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Doctoral Thesis

The Empirics of Deflation and Economic Growth

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature, and that the thesis has not been used to obtain a different or the same degree.

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Prague, July 26, 2018

Signature

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Abstract

This doctoral thesis deals with the relationship between deflation and economic growth. Existing empirical research has focused on the simple link between price growth and GDP growth or introduced narrower price measures as control variables. The goal of the present work is to account for shifts in both demand and supply, so that the effect of price inflation on growth as such could be separated from effects of changes in certain elements of nominal demand and supply.

The work takes two general approaches. First, I use a large macroeconomic panel data set of 20 countries over approximately 140 years to explore long-run and short-run effects of inflation on output growth, after controlling for money supply growth as a demand shifter and oil price growth as a proxy for shifts in supply. In doing so, I use a range of methods such as the vector error-correction model, autoregressive distributed lag model and the fixed effects panel model. Second, I propose a new approach that uses disaggregated sector data from national accounts on output, prices and other variables to explore the link between quantity produced and sector inflation rates. The advantage of the data set is that it is rich in modern-day observations of sector price deflation which are unavailable at the aggregate level. A natural drawback of the sector approach is that it has implications rather for theory than for policy.

There are several important sets of results. First, on the macroeconomic level, various methods do not find general evidence of a positive effect of inflation on growth, be it in the long or short run. Controlling for demand and supply factors yields a slightly negative and statistically significant contemporaneous effect of inflation on growth, which was not shown by other studies that did not use the present control variables. The only exception to this is the Great Depression which shows a positive and significant link between inflation and growth even after controlling for money supply growth and oil price growth. This suggests that there might be circumstances in which price deflation as such is linked to recession, although these appear to be very rare.

Second, on the sector level, there does not seem to be general evidence that price growth leads to higher growth of quantity demanded, after controlling for potential simultaneity with supply factors. This holds across several specifications and samples, although the link is restricted to a contemporaneous one.

Third, robust nonparametric methods applied to sector data show that sector deflation and below-average inflation may be linked to productivity improvements. This approach also shows that productivity can be analyzed as efficiency and that its link to prices can be studied with efficiency-score methods.

Overall, the results extend the current understanding of the link between deflation and growth and suggest new room for empirical research.

Keywords:	deflation; price level; production; economic growth; panel data; time series; economic history.
JEL classification:	E23, E31, C32, C33, N10.

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Chapter 1

Introduction

In the last two decades and especially after the world economic crisis of 2008-09, deflation has again appeared in the center of macroeconomic debates. What started with an overall drop in inflation rates was later accompanied by occasional deflation that appeared during the crisis and in some countries also after it. The debate on inflation has had two natural sources. First, macroeconomic theory found renewed interest in the topic, which had been previously limited to research mainly on the Great Depression and its deep deflation in the United States and later on, to a lesser extent, to the modern Japanese experience with episodic deflation. Second, policy makers logically paid a lot of attention to deflation as most countries follow a positive inflation target around 2 percent.

The key underlying question of most of the debates is whether deflation is linked to weak economic growth and, possibly, to outright recession. To answer this question, several empirical works have appeared that assess the hypothesis most often on cross-country panel data sets. Although they shed some light on the issue, their common disadvantage is that they do not attempt to empirically separate demand-driven and supply-driven deflation. The lack of control variables of aggregate demand and aggregate supply may lead to bias in estimation and incorrect conclusions, since the coefficient estimates of effect of inflation on output growth may take on themselves some effects of other variables that were not controlled for.

The present work provides a more comprehensive view on deflation and economic growth that aims to tackle this and other issues. There are two basic approaches that I take in this work. First, I have compiled a long-run macroeconomic panel data set on output, prices and other variables which spans from the 19th century to 2015 and covers 20 countries. In this macroeconomic approach, I focus on controlling for demand and supply factors by employing money supply and oil prices, respectively, as control variables. I use a range of methods such as vector error-correction models, autoregressive distributed lag models and fixed effects panel models to investigate the links. Second, I step aside from the purely macroeconomic approach to deflation and introduce a new, more disaggregated approach to analyzing price growth and output growth. I use sector data from national accounts on the Czech, Japanese and US economy to look at the relationship between growth of sector output and the growth in its output prices. Again, I focus on controlling for demand and supply factors in order to see whether there is a link in the growth of quantities demanded and the growth of prices of the respective goods. The methods used include panel fixed effects, two-staged least squares and GMM. The appeal of sector data is that it provides us with numerous modern-day observations of sector price deflation which are unavailable on the aggregate level, but the approach obviously also has its drawbacks that I extensively discuss.

The results of both approaches point in the same direction, although by their nature they do not have the same relevance. In the macroeconomic part, using a range of samples and

methods, I do not find significant short-run or long-run evidence of negative effect of deflation on output growth. The short-run association of deflation and recession is limited to the Great Depression and does not generalize to the rest of the sample, including modern Japan. The results suggest that the slight positive link between inflation and growth shown by some studies may be due to missing variables, especially on the demand side. Here, after controlling for money supply growth and oil price growth, contemporaneous estimates rather point to a slight negative association of inflation and growth. In the sector approach, we generally do not find evidence that growth of quantity demanded is positively linked to growth of sector prices, after controlling for demand and supply factors and performing the regressions across a range of samples and specifications.

Importantly, the present work is rather theory-oriented than policy-oriented. The reason is twofold. First, the macroeconomic part works with observations of realized inflation and deflation, not expectations thereof. Since some theories of deflation and recession concentrate on expectations, the present work cannot fully address their validity. There are difficulties with obtaining and employing data on inflation expectations that I discuss in detail and for this reason, their use is beyond the scope of the present text, similarly to many other studies. Second, the sector approach by its nature does not have direct macroeconomic counterparts and therefore cannot yield policy recommendations. Its value added is mostly to our understanding of the microeconomic foundations of theories of deflation and growth.

The text proceeds as follows. In Chapter 2, I lay out two major theoretical approaches to deflation: one that sees deflation as a possible trigger for recession, and one that views deflation rather as a symptom of other processes. Next, I survey the existing empirical literature on deflation and explain in the DAS-DAD framework where its limitations lie and how it can be improved. In Chapter 3 I use the historical data set to explore the relationship between output growth and price growth. First I provide descriptive statistics and then I use VECM, ARDL and fixed effects panel models to look into the link between output growth and price growth across various samples. In most specifications, I control for money supply growth and oil price growth. I pay special attention to the Great Depression and to modern Japan. Chapter 4 suggests a new approach to analyzing deflation. We first extensively discuss the advantages and drawbacks of this approach and explain why sector data could enrich our understanding of the microeconomic core of deflation-recession theories. We then use panel data sets on the Czech Republic, Japan and United States to explore the link between sector price growth and sector output growth, paying special attention to the endogeneity issue. In Chapter 5 we explore a special feature of the sector panel data sets. Using data for the Czech republic, we approach productivity as a form of efficiency and we employ robust nonparametric methods to see whether there is a link between productivity and sector inflation. Chapter 6 concludes and suggests areas for further research.

Chapter 2

Theory and Evidence on Deflation and Economic Growth

2.1 Definition

There are two characteristics that economic literature usually requires in order to declare that there is deflation in an economy. First, "deflation occurs only when there is a general fall in some aggregate price level" (Burdekin and Siklos, 2004, p. 7.). This understanding of deflation naturally mirrors that of inflation. Second, authors usually describe deflation as a 'persistent fall' (Groth and Westaway, 2009, p. 8). It is not generally clear what time span 'persistent' represents, but deflation is not a situation when, for instance, the year-on-year change in the Consumer Price Index (CPI) or the GDP deflator is negative for a month or a few months.

As Salerno (2003) points out, inflation and deflation in the older economic literature denoted increases and decreases in the amount of money in the economy, not increases and decreases in the price level. Changes in the price level were understood to be consequences of changes in the money supply. However, the symptom gradually replaced the cause, leading to the current definition in terms of the price level. In this text, I follow the current definition of inflation and deflation which refers to prices.

A technical note is due. The literature uses the term 'inflation' ambiguously to denote both an increase in the price level and, more generally, any change in the price level, which can take a positive or a negative sign. By contrast, 'deflation' obviously only means a negative change in the price level. I follow this practice, but I use the terms in such a way that it is clear in every instance if inflation denotes only positive change or any change of the price level.

2.2 Characteristics of Literature on Deflation

A reader interested in the theory of deflation and economic growth encounters an interesting feature of the available literature. The association of deflation with recession is in most texts taken rather as an *assumption* of the analysis than a *result* of it (e.g. Tobin, 1975, or Mankiw, 2001) and there is a noticeable lack of comprehensive analyzes of deflation and of its potential link to economic growth. For example, Romer's (2012) *Advanced Macroeconomics*, which is arguably the most commonly used textbook for graduate macroeconomics, has a total of seven references of deflation, but all of them are rather marginal and none of them offers an explanation of the sources and consequences of deflation. Most of the references only deal with the

specific mechanism of debt-deflation.[1] It could be argued that there is little need to analyze deflation if it has hardly ever appeared in the last few decades in advanced countries (with the exception of Japan). However, there seems to be a strong consensus within macroeconomics that deflation could be harmful.

The lack of analysis of deflation in Romer's textbook is not accidental because it stems from a general neglect of deflation in economic literature. Two examples will illustrate this assertion. First, there are currently only two standard-length books exclusively devoted to deflation, namely Burdekin and Siklos (2004) and Bagus (2015). Nonetheless, Burdekin and Siklos (2004) is not a comprehensive general text, but a compendium of texts, some of which have very narrow historical focus. This leaves Bagus (2015) as the only book-length treatise on deflation. Second, journal articles rarely deal with deflation in a general theoretical manner (a notable exception is Salerno, 2003) and they either touch on deflation as a by-product of other analysis or they directly focus on how to prevent deflation without presenting theories on it in the first place.

2.3 Two Theoretical Approaches

The theoretical literature on deflation has one strikingly clear division line that splits researchers into two categories. The first group, which is the more numerous and influential one, tends to approach deflation as a *cause*. These authors show how decreasing prices may affect aggregate demand or financial stability through various channels and mostly conclude that deflation should be avoided. They typically point to the Great Depression as a distinct empirical example (see Figure 2.1 for the concurrent drop in prices and output in the US between 1929 and 1933). By contrast, the second group approaches deflation as a *symptom*. Either deflation can arise as a consequence of economic growth in a regime with constant money supply, which was typically the case of the second half of the 19th century (see Figure 2.1), or it can just as well occur in periods of distressed selling in recessions. Either way, however, economists of this second group argue that deflation should be let to run its course as it is not a cause, but a symptom of forces working in the background. Each approach is discussed below.

2.3.1 Deflation as a Cause

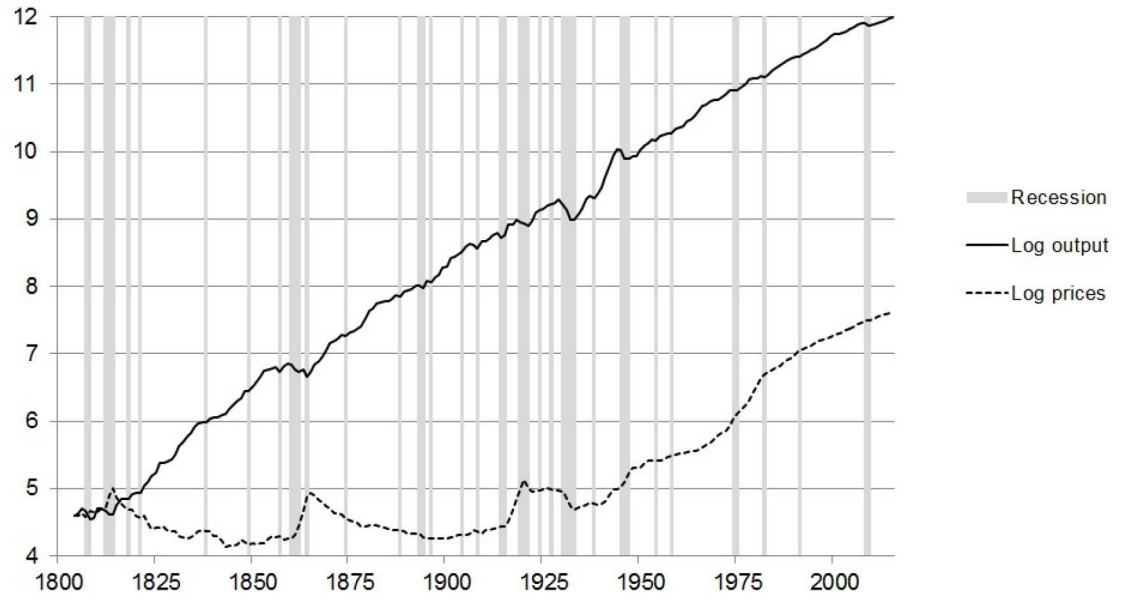
Four basic lines of reasoning according to which deflation is harmful for economic growth can be traced in theoretical literature. I discuss each below.

2.3.1.1 Postponement of Consumption and Investment

The most common argument against deflation is that it causes a delay in spending. More than current deflation, works like DeLong and Summers (1986) and DeLong (1999), Krugman (1998), Bernanke (2002) and Kumar et al. (2003) stressed deflation expectations. If consumers expect

[1] Romer (2012, pp. 526-527) states that economic research has not yet reached definitive conclusions regarding the benefits and costs of inflation and that the relationship between inflation and output growth is negative, but that it is unclear whether the relationship is causal or just statistical. In any case, Romer refers to inflation in general with no specific reference to deflation.

Figure 2.1: US real GDP and Consumer Price Index 1804–2015 (log of index where 1804 = 100)



Source of data: See Appendix 3.A.

prices to fall, they replace current consumption by cheaper future consumption. A similar mechanism may be in place, as the argument goes, for firms which want to avoid investing at high prices if they expect prices of their output to fall. Reduced current consumption and investment leads to a contraction of aggregate demand.

This reasoning depends crucially on our assumptions regarding nominal and real interest rates. These are linked by the Fisher equation $i = r + \pi^e$, where i is the nominal interest rate, r is the real interest rate and π^e is expected inflation. If we assume that r is given by exogeneous factors (i.e., time preferences) and i differs only by a premium (for inflation) or discount (for deflation), then the rate of inflation or deflation does not matter. What matters for intertemporal choice is real variables because the changes in π^e are fully absorbed into i, without affecting r. Higher expected future prices are compensated by higher nominal interest rates. Analogically, lower expected futures prices are offset by lower nominal interest rates, leaving the consumer or investor choice intact.

The conclusion changes, however, if we suppose that the nominal interest is fixed at some level and that it is the real interest rate that adjusts, depending on the rate of inflation. The literature allows for various levels where the nominal interest may be fixed, but a well-known case is that of 'zero lower bound'. Then, $i = 0$ in the Fisher equation implies $r = -\pi^e$, so that the rate of expected deflation directly determines the real interest rate. Hence, deeper deflation means higher real interest rates, which reduce current consumption and investment and lower aggregate demand.

There is a second reason why real interest rates may be affected by deflation. The Mundell-

Tobin effect states that due to people's portfolio decisions, inflation does not influence only the nominal interest rate, but also the real interest rate. When prices start to fall, holding cash earns a return and people shift a part of their wealth from interest-bearing assets to money balances. That causes the real rate of interest to rise, which again lowers current consumption and investment.[2]

Overall, the 'postponement' argument links the rate of inflation to the intertemporal decisions of economic agents. Deflation deters consumers and businesses from current purchases and induces them to hoard money instead—thanks to deflation, they can earn risk-free return just by holding it. At the same time, deflation causes the real interest rate to shoot up and deters businesses and consumers from borrowing. This underlying idea, stressed by Krugman (1998), again follows up on Keynes (1936). Bernanke (2002, p. 2) also highlights that the central problem is the combination of zero nominal interest rates and deep deflation: "In a period of sufficiently severe deflation, the real cost of borrowing becomes prohibitive. Capital investment, purchases of new homes, and other types of spending decline accordingly, worsening the economic downturn."

The literature does not seem to offer a clear line of criticism of the postponement argument. Several lines of reasoning can be traced. First, Pigou (1943) and Patinkin (1965 [1956]) laid out the so-called real balances effect. A drop in the price level—ceteris paribus—increases the real money balances that consumers and business hold. This encompasses both liquid money and securities such as government bonds. The increased wealth leads to higher purchases and hence to greater aggregate demand. Ireland (2001) points out that studies such as Krugman (1998) do not take the real balances effect into account because under Ricardian equivalence, households do not view government bonds and money as net wealth, which does not allow the real balances effect to operate.

Second, an inherent problem with the postponement argument is its implications for future periods. If economic agents postpone purchases to the future in anticipation of deflation, the alleged current loss in aggregate demand should be weighed against a future gain. However, the existing literature is rather silent on this question and assumes that what matters is mainly current aggregate demand. The postponement argument also does not explain when the postponements end. That is, in the extreme, a persistent deflation would cause economic agents to delay purchases infinitely, so that the future gain would never materialize. But endless postponements of purchases 'to the next period' would also run against the agents' basic rationality. If such endless postponements are possible in reality is not discussed in the literature; alternatively, it is argued (Krugman, 1998) that such a long-run perspective is not the purpose of the analysis, echoing Keynes's (1936) *General Theory*.[3]

Third, completely missing from the literature is an apparent asymmetry in the postponement argument on deflation. The argument only approaches the economy from the point of view of *buyers*, who naturally look for ways to buy cheaper. But all economic agents are also *sellers*—firms sell products and services and most individuals sell their work. Hence, if deflation induces

[2]Neither argument why real interest rates may be affected by the rate of inflation is limited to cases when inflation turns into deflation. The same applies to disinflation, i.e., a decreasing rate of inflation.

[3]The assumption that deflation could depress present spending without boosting spending in future periods would be equivalent to the assumption that inflation could bring all spending to the present time without depressing it severely in the periods to come.

economic agents to buy later, inflation induces them to produce and work later because they will be able to receive higher prices for what they sell. In macroeconomic terms, if deflation weakens aggregate demand, then inflation weakens aggregate supply, and vice versa. Given that equilibrium output is determined by the interaction of aggregate demand and aggregate supply, it does not seem straightforward that boosting one while weakening the other should improve the overall outcome.[4]

2.3.1.2 Nominal Rigidities

Deflation may be harmful in an environment of nominal rigidities, especially wages. If deflation of product prices reduces sales, firms may not be able to pass the reductions to wages and prices of inputs. In particular, labour unions, minimum wage laws or general unwillingness to accept nominally lower wages are often cited as reasons for a downward rigidity of wages.[5] This downward rigidity may lead to narrowing of profit margins, cutbacks in production and potential layoffs and bankruptcies. Kumar et al. (2003) emphasize that this could lead to a vicious cycle where the combination of deflation with sticky wages causes layoffs of workers, who then cut back on their purchases and accelerate deflation even more. Even when wages adjust downward somewhat, this adjustment may not stimulate enough hiring to compensate for the lowered nominal wages. As a result, aggregate demand would still fall.

Finding the extent of 'objective' downward nominal rigidities in present-day economies is difficult because nominal rigidities may be themselves co-determined by the recent rate of inflation in the system. Currently, after decades of almost uninterrupted inflation and nominal wage increases, both the legislation on wages and workers' attitudes may be tilted towards the expectation of regular nominal increases simply because there are very few people who have experienced repeated and sizable wage cuts in their working life. Seltzer (2010) provides a summary of literature on the behaviour of wages in the late 19th century which lends some support to the hypothesis that nominal rigidities may be dependent on the monetary system and its average inflation rate: "The general thrust of this evidence suggests that individual wage cuts occurred more often in the late 19th and early 20th centuries than subsequent to the Second World War". (Seltzer, 2010, p. 114.) Hayek (1990 [1976]) criticized the idea that rigidities are an 'unalterable fact' and argued that monetary policy adjusted to accommodate rigidities would only reinforce them. Okun (1981) found that although there is anecdotal evidence about downward price rigidity, it does not seem to be supported by available studies of price setting behaviour. Carlton (1986) investigated the behaviour of input prices in US manufacturing in 1957–1966 and found that although there was price rigidity, it appeared to be symmetric around zero: "There is no evidence that there is an asymmetry in price rigidity. In particular, prices are not rigid downward." (Carlton, 1986, p. 638.) Dhyne et al. (2005) analyzed product prices of a large number of European companies and reached similar conclusions: there are no signs of downward price rigidity and price decreases are comparable in magnitude to price increases.

[4]The reason why postponement of demand receives much attention while postponement of supply receives almost none might be simple: scholars who promote the postponement argument against deflation follow the Keynesian tradition (based on Keynes 1936) and regard aggregate demand as the primary subject of analysis. As a result, the symmetric problem with inflation and aggregate supply is outside their focus.

[5]The reasoning with nominal rigidities is somewhat problematic since it is not usually explained whether the blame should lie with deflation or rather with the inflexibility of the system.

There is an interesting and important link between nominal rigidities and the 'postponement' argument from the previous section. Although it may seem logical to deduce that more price and wage flexibility would help economic adjustments and would therefore make deflation more acceptable, DeLong and Summers (1986) or Palley (2008) argue conversely. In their view, since deflation has other adverse effects—mainly the postponement of purchases—price and wage rigidity may actually be desirable as it stops the spreading of deflation across the economy. DeLong and Summers (1986) argue that while flexible prices clear markets in the present period, they cannot do anything about the fact that deflation increases the real interest rate and depresses current consumption through intertemporal choice. This is the factor that lowers current aggregate demand. They assert that nominal rigidities have in fact helped to stabilize output in recent decades and that if prices had fallen more in the Great Depression, the output loss would have been even greater. In DeLong's and Summer's view, nominal rigidities would prevent *any* deflationary spiral in the first place, avoiding output losses.

Interestingly, there does not seem to be a consensus about whether nominal rigidities should be reduced or reinforced.

2.3.1.3 Debt Deflation

The third common argument against deflation is that it may prove harmful in an environment of high indebtedness. Fisher (1933) asserted that if economic agents (especially firms) have their debt contracts specified in nominal terms, then deflation causes the real value of their debt to rise. Since this real growth in debt is not matched by a similar real growth in their revenues, many firms find themselves unable to pay off debts and declare bankruptcy. In addition, the very effort to sell assets in order to pay down debts makes the situation only worse as these efforts further depress prices and reinforce the increase in real debt burden. This gives rise to another deflation spiral—namely, debt-deflation spiral—which causes a contraction in both aggregate demand and aggregate supply. (Aggregate supply is affected since bankrupt firms are assumed to stop producing.) In short, the debt-deflation argument is a special case of the nominal-rigidities reasoning where the subject of rigidity is the nominal nature of debts.[6]

In a certain sense, Fisher's (1933) argument is an opposite to Pigou's (1943) and Patinkin's (1965 [1956]) real balances effect mentioned above. Pigou and Patinkin focus on the increase in real wealth under deflation that may stimulate purchases. However, in Fisher's view, with some assets this increase in real wealth may only be fictitious: in case where one's asset is another one's liability, the debtor may be unable to repay the liability once his flow of income becomes too strained under deflation. Therefore, the increase in the creditor's wealth is only 'on paper' since the debtor is insolvent. This is not the case with liquid money (which is assumed to be an asset but not anyone's liability) and may not be the case with relatively low-risk government bonds, but it might well be the case with many private debt instruments. Feldstein (2002) stresses the danger of deflation especially for firms with long-maturity debt.

The key assumption of Fisher's theory is that deflation must be *unanticipated*. Otherwise, an anticipated path of prices could already be reflected in debt contracts. Indeed, it is customary

[6]Fisher (1933) put the blame for recessions accompanied by debt-deflation partly on deflation itself and partly on the preceding increase in debt. A little known predecessor in this line of thought is Carroll (1972 [1964]) who, already in the 19th century, opposed the build-up in debt and linked it explicitly to ensuing sharp drops in prices.

for firms that issue corporate debt to have special clauses in their debt prospectuses that allow them to call (repay) the debt early if they think the debt will be difficult to service or to have the coupon rate mirror the current interest rate on the market. There is no general limitation of what the debt contract may specify, so the debtor can prepare himself for any potential scenario if he deems it likely.[7] [8]

Hülsmann (2008) criticized the debt-deflation theory for several reasons. First, bankruptcies do not mean disappearance of assets but rather their transfer to new owners. If a previous business model failed for too much leverage, bankruptcy allows the firm to replace debt with equity and therefore find a more viable way of functioning.[9] Second, debt-deflation may be an important correction mechanism in situations where the economy reaches unsustainable levels of debt. The 2008–09 financial crisis revived economists' interest in the amount of financial intermediation and debt (see Reinhart and Rogoff, 2011, and Schularick and Taylor, 2012) and suggested that leverage in the economy cannot increase without bounds. Third, Hülsmann put debt-deflation into a broader perspective of wealth redistribution. Debt-deflation clearly redistributes wealth from debtors to creditors. However, if debt-deflation is a reaction to previous inflation and increase in indebtedness of the economy, then it is only a reversal of the previous opposite inflationary redistribution of wealth from creditors to debtors. Therefore, from the distributional point of view, there should be nothing asymmetric caused by inflation and deflation.[10]

At this point, however, the argument about the primary importance of *current* spending returns. Tobin (1993) stressed that debtors have higher marginal propensities to spend from their wealth than creditors, so that redistribution of wealth from debtors to creditors through deflation lowers aggregate demand.[11] It seems that the whole debate reverts back to the validity of Keynes's (1936) claim of excess savings and of his stress on short-run dynamics. This debate is, however, outside the scope of this text.[12]

[7] The debt contract may for example specify that the nominal value will follow the CPI, the GDP deflator or any other price index if this price index exceeds certain boundaries relative to its initial value. This would keep the real value of debt unchanged for the investor and at the same time shield the issuer from the debt-deflation scenario.

[8] This is why it is difficult to think of debt-deflation as a relevant mechanism in Japan after more than 20 years of Japanese experience with mild deflation. Firms and individuals would have already adjusted their contracts after two decades of deflation if they had considered it to be important. I discuss this more in Section 3.4.5 on Japan.

[9] The practical question here is how fast the transfer of ownership can happen so that production is not paralyzed. This partly depends on the pace of bankruptcy proceedings in courts.

[10] Yet, there is still the aforementioned argument that when the debtor is unable to pay off his debts, both the creditor and the debtor lose and the result is not a pure redistribution of wealth.

[11] "That inside assets and debts wash out in accounting aggregation does not mean that the consequences of price changes on their real values wash out. Price declines make creditors better off and debtors poorer. Their marginal propensities to spend from wealth need not be the same. Common sense suggests that debtors have the higher spending propensities—that is why they are in debt!" (Tobin, 1993, p. 60.)

[12] The debt-deflation literature is currently much richer than Fisher's (1933) well-known contribution. Von Peter (2005) distinguishes between three versions of debt-deflation: through the overall price level (Fisher), through asset prices (Minsky) and through the impairment of loan mechanisms (Bernanke-Gertler). The latest variation on debt-deflation by Bernanke and Gertler (1989) suggests that firms' net worth is important in overcoming the asymmetry of information between firms and creditors (banks) about the firms' health. If net worth drops due to debt-deflation, firms are unable to obtain loans.

2.3.1.4 Ineffectiveness of Monetary Policy

The fourth argument to avoid deflation is not concerned as much with consumers and firms as with the effectiveness of monetary policy. Therefore, it is rather a practical, policy-oriented argument, while the three listed in Sections 2.3.1.1 to 2.3.1.3 are theoretical arguments. If the nominal interest rate decreases to zero, standard monetary policy loses effectiveness. It cannot reduce the interest rate any further since short-term securities such as government bills become substitutes to cash—they are risk-free (or almost risk-free) and they yield zero nominal interest. These conditions often coincide with the Keynesian idea of liquidity trap, which is generally a situation in which the public refuses to buy securities with new money injected into the system and hence does not reduce the nominal interest rate. Deflation may give rise to such a situation. First, with deflation nominal interest rates may be low or zero because the inflation premium is negative, or because monetary policy has actively sought to bring them down. Second, since deflation promises risk-free return, there is an incentive for the public to hold cash instead of buying securities. This renders standard monetary policy ineffective.[13]

The obstacle posed to monetary policy has inspired a large amount of research on when and how monetary policy should react to the above situation, e.g. Bernanke (2002), Auerbach and Obstfeld (2004), Mendoza (2006), Dotsey (2010) or Kuroda (2016). Casiraghi and Ferrero (2015) suggest that whether deflation is harmful or not is of secondary importance because its main disadvantage is already the very fact that it imposes limits on monetary policy. They argue that while inflation can always be countered by higher nominal interest rates, deflation cannot be because nominal rates have their lower bound at zero.

From this perspective, Friedman (1969) represents a distinct exception in terms of recommendations for monetary policy. Since the nominal interest rate is the cost of holding cash (i.e., the foregone return), the public would choose to hold more cash if nominal interest rates were zero. Friedman argued that the central bank can achieve zero nominal rates at almost no cost because it can create additional money virtually for free. Therefore, if additional social utility can be achieved at almost no additional social cost, this should be the optimal monetary policy. If this is the case, then the resulting rate of inflation must be equal to the opposite value of the real interest rate ($i = 0$ in the Fisher equation implies $r = -\pi$). If the real rate of interest is positive, deflation is the optimum. That is, Friedman (1969) directly suggested that zero nominal interest rates and deflation are the best outcome. It is remarkable that Friedman's argument received rather little response and that there have been almost no attempts to reconcile Friedman's recommendation with the other arguments that rather warn against deflation. Sanches (2012) suggests that the social gain from zero interest rates is rather small and that there are more important considerations for monetary policy than Friedman's argument, which is why it is almost never mentioned in monetary policy debates.[14]

[13] White (2006) includes the zero lower bound on nominal interest rates among other rigidities—i.e., the three general rigidities are (1) wage rigidities, (2) nominally fixed debts, and (3) the zero lower bound on nominal interest rates.

[14] It would be a mistake to suggest, however, that Friedman's overall message was to allow deflation. Friedman's (1969) contribution to the debate on deflation stands out as solitary and atypical compared to his other works. From his and Anna Schwartz's (1963a) *Monetary History* until his last article (Friedman, 2005), he endorsed constant increases in money supply which effectively preclude any deflation. I discuss this more in Section 3.4.4 on the Great Depression. Also, Friedman and Schwartz (1963a, p. 134, footnote 52) write "If one regards

2.3.2 Deflation as a Symptom

In contrast to authors listed in the previous section, some economists view deflation—and price changes in general—rather as a symptom of other, independent processes. In their view, attention should be paid to where deflation comes from, rather than to deflation per se and its possible secondary effects. The key distinction of this part of literature is the focus on categorization of deflation according to its sources.

2.3.2.1 Sources of Deflation

Rothbard (1991) provided a brief typology of deflation, but it was Salerno (2003) who laid out in detail four major sources of deflation and showed how this categorization can be applied to historical episodes. Salerno's typology includes (1) bank-credit deflation, stemming from deflationary monetary policy or bank runs, (2) cash-building deflation, caused by individuals' change in preferences towards holding more money, (3) confiscatory deflation, where the government seizes a part or all of people's money balances, and finally (4) growth deflation, arising from increasing economic output. Importantly, while some types of deflation like bank-credit deflation and cash-building deflation are often associated with recessions, growth deflation is a sign of economic growth. This illustrates that when regarded as a symptom, there is no simple way to match deflation only with recessions or only with booms.[15] [16]

Growth deflation is of special interest since it may explain long periods of deflation with increasing output observed in the gold standard era of the late 19th century (see Figure 2.1 for the case of the United States). Economic growth can take two forms: extensive growth, where original factors of production such as labour and land increase in amount, and intensive growth, where the factors' productivity increases, either thanks to investment or thanks to technological or organizational changes.[17] Intensive growth is especially interesting for the study of deflation since it is equivalent to lower costs of production per unit of output. Therefore, as firms have lower marginal costs, they can charge lower prices to attract more marginal demand. Supply curves move downward and lead to higher equilibrium quantities and lower equilibrium prices. At the macroeconomic level, deflation stemming from either type of economic growth is easily seen from the quantitative equation (in Fisher's form) $M \cdot V = P \cdot Y$. If money velocity is assumed to be constant, then any increase in output greater than increase in money supply

the deflationary price trend as an evil and a horizontal price trend as preferable, as we do, though with some doubts,..." This statement illustrates Friedman's general scepticism towards deflation.

[15] Some empirical studies such as Bordo and Redish (2003) use the terms 'good' and 'bad' deflation according to its link with either booms or recessions. The confusing aspect is that by 'good' deflations, Bordo and Redish usually mean what Salerno calls growth deflation—i.e., deflation typical for the end of the 19th century when output rose and prices fell or stayed unchanged. However, 'good' and 'bad' deflation are empirical terms and should not be equated with Salerno's typology of deflation. As the approach by Rothbard (1991) and Salerno (2003) views deflation rather as a symptom (not cause), it does not ascribe them 'good' or 'bad' qualities. Thornton (2003, p. 8) writes: "With the exception of confiscatory deflation, deflation *per se* should be viewed as an integral part of the economic process that helps the capitalist economy (...) adjust to both good phenomena, such as economic growth, and bad economic phenomena, such as war." (Emphasis original.)

[16] Bagus (2015) further elaborates on the typology of deflation and provides two detailed historical examples.

[17] I thank Joseph Salerno for suggesting this distinction between two types of growth, as opposed to an earlier version which was slightly ambiguous.

must necessarily cause the price level to fall. Deflation resulting from economic growth is equivalent to the aggregate supply curve shifting to the right in the AS-AD diagram.

Hayek's (1931) *"Paradox" of Savings* is an important early work on the effects of intensive growth. Hayek argues in detail how the structure of production and expenditures adjusts to investment while the amount of money in the economy stays the same. Real wages increase not through nominal increases, but through a drop in consumer prices allowed by lower unit costs—i.e., through deflation. Judging by today's prevailing view, Hayek went very far: he argued that healthy economic growth must be accompanied by deflation.[18] The possibility of growth deflation stemming from productivity growth has been stressed by Okun (1981, Selgin (1997, 1999), Šíma (2002), Salerno (2003), Leamer (2011), Castañeda and Schwartz (2012) and Bagus (2015). Reisman (1998) argued that deflation stemming from economic growth and deflation stemming from changes in money supply or money demand are completely different phenomena which only have a common end result.[19]

2.3.2.2 Adjustment of Firms to Deflation

The approach to deflation as a symptom has an important feature: it allows to see the firm as an active player. I narrow the discussion to two most important points.

First, Selgin (1997, 1999) suggests that if there is deflation stemming from productivity increases, most of the arguments against deflation that I listed in Section 2.3.1 do not hold. Suppose that firms invest in production to cut unit costs and increase profitability and hence can afford to lower prices to reach more marginal demand. Then higher returns achieved in their businesses naturally translate into higher real interest rates on the capital market. This rise in the real interest rate is itself the *effect* of firms' higher profitability—in other words, it is a symptom of a new market equilibrium. Although the price cuts cause deflation, the nominal interest rate may stay unchanged since real interest rates have increased in the meantime. Moreover, investment boosted labour productivity, so that real wages increased. Although consumers face higher real interest rates, they also have higher real income. In short, Selgin asserts that with deflation resulting from productivity improvements, higher real interest rates do not depress investment or consumption.[20]

[18] Selgin (1997, mainly in Chapters II and IV) describes the important debate on whether real wage growth should materialize through increasing nominal wages or rather through decreasing general prices. This debate was relatively intense until approximately World War II.

[19] Friedman and Schwartz (1963a, p. 41) illustrate how deflation and economic growth may interact differently: "Contrast, for example, this result with the widely accepted interpretation of British experience in the 1920's, when Britain resumed specie payments at prewar parity. The prewar parity, it was said, overvalued the pound by some 10 per cent or so at the price level that prevailed in 1925 at the time of resumption (prices by then having fallen about 50 per cent from the postwar price peak); hence, the successful return to gold at the prewar parity required a further 10 per cent deflation of domestic prices; the attempt to achieve such further deflation produced, instead, stagnation and widespread unemployment, from which Britain was unable to recover until it finally devalued the pound in 1931. On this interpretation, the chain of influence ran from the attempted deflation to the economic stagnation. In the greenback episode, a deflation of 50 per cent took place over the course of the decade and a half after 1865. Not only did it not produce stagnation; on the contrary, it was accompanied and produced by a rapid rate of rise in real income. The chain of influence ran from expansion of output to price decline."

[20] A shortcoming of Selgin's argument may be that it does not explain how the firms increased productivity in the first place. If this was enabled by an increased supply of savings (loanable funds) which first lowered the

The same reasoning can be applied to the debt-deflation theory. If firms invest, cut unit costs and lower prices, they do so deliberately to increase their real profit. The ensuing deflation increases the real value of their debt, but they can service it thanks to higher real profits. The same applies to consumers whose real debt increases, but real income does, too. To sum up, Selgin contends that deflation-recession arguments cease to hold if deflation is productivity-driven. His conclusion is intuitive if one realizes that deflation of this sort results from firms' own profit-maximizing decisions. In Chapter 5, we return to Selgin's reasoning and look into the relationship between productivity and prices in sectors of the Czech economy.

Second, even if firms are not the initiators of deflation, they may be able to react to it efficiently. The most important seems to be the question whether firms can adjust to persistent, ongoing deflation without having to cut production. Bagus (2015) highlights that the key condition for the firm is to maintain price differentials between its inputs and outputs. If this profitability condition is met, then it does not matter whether the economy is in deflation and with nominal interest rates at zero, which for example Krugman (1998) considers to be highly detrimental. Even considerably positive real interest rates are acceptable for firms if the price differentials are wide enough. According to Bagus, it is a part of the entrepreneur's function to anticipate price movements and therefore to bid down input prices early enough to maintain profitability. Nominal rigidities on the part of workers and suppliers of inputs may obviously arise, but the rigidity is voluntary and can always be reversed to maintain employment. Interestingly, this reasoning suggests that expected deflation facilitates adjustment because it gives entrepreneurs a chance to bid down input prices early enough, while authors like DeLong and Summers (1986) or Krugman (1998) consider expected, entrenched deflation to be the most dangerous scenario due to postponement of purchases.

To summarize, the stream of literature that approaches deflation as a symptom recognizes a type of deflation that firms themselves initiate (productivity-driven) and, in addition, even if deflation stems from other sources, it sees few reasons why firms should cope with it worse than with inflation.[21]

interest rate, then even after boosting productivity and increasing the real return on investments the real interest rate might not increase in net terms. However, Selgin's order of events would hold if productivity increased based on technological or organizational improvements which did not require firms to take up more funds from the capital markets. Overall, Selgin's reasoning is still valuable in showing that if deflation is a symptom of increasing productivity, then businesses and consumers have an increased *capacity* to pay a certain level of interest.

[21] The economists who lean towards the 'symptom' approach to deflation are most often associated with the current Austrian school of economics. Nevertheless, as Bagus (2003) illustrates, although the Austrian school has been the most open to the possibility of deflation compared to other schools of thought, its main historical figures like L. von Mises, F.A. Hayek and M. Rothbard were sometimes inconsistent in their practical recommendations and their view on deflation evolved over time. A good example in this respect is F.A. Hayek. Hayek considered deflation natural and even necessary if it stemmed from economic growth in an environment with fixed money supply (Hayek, 1931). However, his stance was more ambiguous when it comes to deflation occurring as a correction of a previous inflationary boom and as a liquidation of malinvestments. He portrayed such deflation as necessary in Hayek (1975 [1933], 1967 [1931]), but elsewhere (Hayek, 1932) he admitted that it could be countered by policy as J.M. Keynes suggested.

Humphrey (2003) surveys opinions on deflation among classical economists D. Hume, H. Thornton and D. Ricardo. His review indicates that they had a critical stance (or were willing to accept deflation only in certain circumstances such as reversal of high inflation and return to the gold standard), but at the same time were not as dismissive of deflation as later authors. On the whole, very few economists seemed to be willing to accept deflation of any kind at any time.

2.3.3 Selected Theoretical Issues Important for Empirical Research

2.3.3.1 Deflation and Disinflation

The debate about the risks and merits of deflation is in many cases also an implicit debate about disinflation. Consider some of the arguments against deflation from Section 2.3.1. Deflation is said to deter consumers from purchases since it offers lower prices in the future. But similarly, a consumer who was planning to buy certain durable goods early because he was expecting a 10% annual inflation might postpone the purchase when expected inflation drops to 1%—with such a slow rate of inflation, he has little reason to hurry. Presumably, a sharp disinflation from 10% to 1% may deter more purchases than a switch from +1% inflation to -1% deflation.

In the same vein, nominal rigidities may not exist only in terms of an absolute fall of wages and prices, but also in terms of a slowdown in their growth. Workers accustomed to an inflationary environment expect wages to increase 10% every year (which was the reality in the 1970s and 1980s in Western economies and in the 1990s in post-communist economies), so they may strongly resist a slowdown in wage growth to, say, 5% a year. It is likely that people resist more an absolute decline in wages than a slowdown in their growth, but that is only a matter of the magnitude of the resistance, rather than a matter of its existence.

Finally, debt-deflation, which is a special case of nominal rigidities, works similarly for disinflation. A firm expecting high inflation may issue a large amount of debt at high nominal interest rates because it expects that the nominal value and the interest will be 'inflated away', so that it will pay smaller and smaller amounts in real terms. If disinflation unexpectedly appears, this plan proves erroneous and the firm has to pay higher real amounts than it expected. Debt-deflation may work much like debt-disinflation.[22]

The only argument against deflation which does not hold for disinflation is the practical monetary-policy argument. If deflation is accompanied by very low or zero nominal interest rates, then monetary policy is less effective than with positive rates of inflation.

Altogether, most arguments against deflation hold also against disinflation. This is essential for empirical research in the following chapters. As I show in Section 2.4, many empirical studies on deflation and economic growth rely on macroeconomic data sets which have few observations of deflation because they refer to the last several decades when deflation has been sporadic. This approach is not optimal, but it is not worthless: as explained above, if we are interested in the effect of deflation on growth as opposed to inflation, we should also be interested in the effect of low inflation on growth as opposed to high inflation, because the underlying reactions of consumers and firms may be similar.

Still, the goal of the following chapters is to provide as many observations of deflation as possible. In Chapter 3 I use a macroeconomic data set which has relatively many deflation observations since it spans deep into the 19th century. Still, the majority of observations are of positive inflation due to the prevalence of the 20th century in the sample.

[22] The similarity of deflation and disinflation is pointed out by numerous authors, e.g. Borio and Filardo (2004), von Peter (2005) or Groth and Westaway (2009).

2.3.3.2 Expectations: Anticipated and Unanticipated Deflation

The theoretical discussion above reveals that each deflation-recession argument has its own assumption on deflationary expectations. The 'postponement' argument against deflation hinges on the assumption of *anticipated* deflation. Consumers and firms must either expect existing deflation to continue for some time or new deflation to appear in the future in order to postpone purchases. If deflation was expected to end soon, there would be little sense in postponing spending. In contrast, the argument based on nominal rigidities and debt-deflation rather builds on unanticipated deflation. If firms expected deflation, they would only enter into debt contracts that take deflation into account and they would attempt to bid down input prices early enough to prepare for the upcoming drop in their output prices. In short, what makes nominal rigidities harmful is unanticipated deflation which catches firms unprepared and with contracts already signed.

There are two issues related to expectations and empirical research. First, it is clear that deflation cannot be anticipated and unanticipated at the same time. This has implications for empirical research: in judging episodes of deflation, all of the potential effects of deflation cannot be applied at the same time and each episode should be described either as the anticipated or the unanticipated case. I discuss the likely nature of deflations in the sections on Great Depression and Japan (Sections 3.4.4 and 3.4.5, respectively).

Second, in conducting empirical research, it is important do decide whether to rely on readings of actual (realized) inflation and deflation or whether to use a measure of inflation expectations. The merits and weaknesses of both options are a mixture of theoretical an practical observations. If, for example, the theory about postponement of spending stresses expectations of deflation rather than observed deflation itself, there is the risk that using actual observed deflation in empirical research will not address the theory at hand. If actual deflation quickly leads to deflation expectations, then observed deflation may act as a good proxy for deflation expectations. But if there are other factors that lead economic agents to expect inflation despite current deflation, then observed deflation fails as a proxy for expectations and the results may not address the theory in question. The mentioned factors that affect people's expectations may be various. For one thing, there might be the general perception that a deflationary shock is only temporary due to its nature (worldwide drop in commodity prices, changes in regulated prices, etc.). But expectations might also be formed based on the record of monetary policy and its commitments. If there is a strong belief that monetary policy will offset any lingering deflation, then expectations of deflation might not appear even if deflation is observed in the short run. This case is relevant for the the past few decades in most developed countries where central banks have set above-zero inflation targets and managed to maintain inflation above zero.

This discussion suggests that it would be optimal to have a measure of inflation expectations as an input for econometric analysis. However, inflation expectations are much harder to measure and obtain. While there is a rather unambiguous way how to measure realized inflation, there is ambiguity in how to measure inflation expectations. Christensen's (2009) analysis of inflation expectations during the 2008-09 financial crisis is a useful illustration. Christensen compares inflation expectations provided by the Survey of Professional Forecasters and inflation expectations implied by the difference in yields of inflation-protected and regular

(not protected) US government bonds. There are many problems that arise from his analysis. First, inflation expectations provided by the Survey of Professional Forecasters and inflation expectations implied from government bond yields diverged sharply at the height of the 2008-09 financial crisis. This raises questions about the reliability of these sources. Second, there was a sharp drop in inflation expectations in autumn 2008 as indicated by government bond yields, but this drop was so short-lived that any empirical analysis using annual data would probably fail to detect this drop and reversal in expectations, although this episode is of major importance for macroeconomic research. Only monthly data would capture the hectic changes of inflation expectations during the crisis, but monthly data of inflation expectations would in turn prevent using other time series which are not available in this frequency. Third, both methods discussed by Christensen rely on expectations by professional forecasters or financial markets. These may be different from expectations formed by regular consumers and small businesses.

As I discuss in more detail in the following section, several studies such as Bachmann, Berg and Sims (2015), Hori and Shimizutani (2005) and Ichiue and Nishiguchi (2014) use survey data from consumers to assess the impact of changes in inflation expectations on consumption. These studies yield mixed results, but some of them also reveal serious problems in measuring inflation expectations. For instance, Ichiue and Nishiguchi (2014, p. 1100), referring to *quantitative* inflation expectations by Japanese consumers between 2006 and 2013, state that "there are too many integers, too many zeros, too many multiples of five, and too few negative numbers" in consumers' 1-year, 5-year and 10-year inflation expectations. As a result, their baseline specifications had to rely on qualitative rather than quantitative estimates of future inflation by consumers.

In short, measuring inflation expectations is much more complicated than measuring actual inflation. The task becomes even more complicated as one would want to measure historical inflation expectations (see, e.g., Cecchetti, 1992). Even though using inflation expectations in empirical research is theoretically a better option for addressing some of the deflation-recession arguments, the price to pay is high from the practical point of view. In the present work, I rely on actual measured price changes in order to explore long-run historical data as well as more disaggregated data on prices. Yet, it is important to keep in mind the above limitations of using actual inflation which does not have to go hand in hand with inflation expectations.

2.4 Survey of Empirical Literature

2.4.1 Overview

Relatively many empirical studies have dealt with the relationship between economic growth and growth of prices. However, as I show below, there are issues with their sufficiency for drawing conclusions about deflation and growth.

Table 2.1 offers a summary of all relevant empirical studies on the relationship between growth in aggregate output (GDP) and growth in prices (mostly CPI). A separate part at the bottom of the table complements this by listing studies on the link between consumption growth and inflation or inflation expectations, given that this direction of research has received quite a lot of attention in recent years.

The last column captures the main message of Table 2.1: from studies analyzing GDP growth and inflation, only 4 out of 13 in total found a strong link between deflation and recession. Most of the studies either found no link, in which case I also include the opposite result (inflation harmful for growth), or they found a weak link, in which case the deflation-recession association was only found for one historical subsample but not for majority of the data. In addition, by 'strong' deflation-recession link I only mean a statistically significant relationship. This rarely coincides with an economically significant relationship (i.e., coefficient estimate far from zero).

2.4.2 Individual Studies

Barro (1995), McCandless and Weber (1995) and Gylfason and Herbertsson (2001) all focus on post-World War II data and differ mainly in their method. McCandless and Weber (1995) do not find any correlation between inflation and output growth. Barro (1995) and Gylfason and Herbertsson (2001) both report a negative effect of a steep increase in inflation on output growth. These results are expected since their authors use large panels with many developing countries and these have often had very high inflation which frequently coincided with economic crises. However, the relevance of these works for the study of deflation may be limited since deflation was very infrequent in annual data in their time span.[23]

When advanced economies experienced very low inflation in 2002–2003, some researches wanted to avoid the problem of the above studies and turned to pre-World War I data with more frequent deflation. Bordo and Redish (2003) and Bordo, Lane and Redish (2004) focus on the classical gold standard period in 1870–1913 and 1880–1913, respectively. They find no evidence of prices influencing output in these periods and side with the hypothesis of 'good' deflation.[24] Beckworth (2007), who analyzes the classical gold standard period in the United States, reaches similar conclusions and concludes that "there is merit in acknowledging both malign and benign deflation"(p. 196). The obvious drawback of these studies is the sole focus on pre-World War I data and only for several countries.

Several studies have covered samples that are longer in time. Atkeson and Kehoe (2004) are an often-cited study that looks at a sample spanning from the 19th century until the modern day. Their general conclusion is that inflation had at best a very small positive impact on economic growth: their overall coefficient estimate of the effect of inflation on growth is positive at 0.08 and statistically significant, but the the economic magnitude is small. The coefficient estimate at 0.08 means that it would would take a 12.5 percentage point drop in the inflation rate to reduce GDP growth by 1 percentage point. Atkeson and Kehoe also highlight that the Great Depression is different from the rest of the sample. Borio and Filardo (2004) and later Borio et al. (2015) complement the study of deflation and growth by looking at asset price cycles and credit cycles. They find that not all deflationary episodes are costly in terms of output, but those that are costly are often marked by concurrent asset price busts and credit busts.

[23] See McCandless and Weber (1995) and Gylfason & Herbertsson (2001) for summaries of older studies of the relationship between inflation and output growth. Practically all of them also use only post-war data.

[24] "Our results show that the deflation in the late nineteenth century gold standard era in three key countries reflected both positive aggregate supply and negative money supply shocks. Yet the negative money shock had only a minor effect on output. (...) Thus our empirical evidence suggests that deflation in the late nineteenth century was primarily good." (Bordo, Lane and Redish, 2004, p. 15.)

Overall, they suggest that deflation should be looked at as a part of boom-and-bust cycles and not always the root cause of the crisis. Unlike these studies, Bordo and Filardo (2004) do not report results of a regression analysis between output growth and price growth (and are not included in Table 2.1), but describe in detail the frequency and appearance of deflation in the 19the century and in the first half of the 20th century. They find that there is no general association of deflation with recession and that "current concerns about deflation may seem somewhat overblown" (Bordo and Filardo, 2004, p. 28).

By contrast, Guerrero and Parker (2006), also using a long panel data set, side with the opposite view. They find a lagged negative impact of deflation on economic growth, although the economic significance (the magnitude of the coefficient estimate) in their longest sample is rather small: a one percentage point drop in the inflation rate below zero leads to a drop of 0.118 percentage points in GDP growth. The coefficient estimate is much bigger (0.296) for their postwar dataset. Benhabib and Spiegel (2009) explore a non-linear relationship—i.e., one that changes with the crossing of a certain threshold in the inflation rate. They conclude that the relationship is an inverted U-shape: inflation positively affects economic growth until approx. 3.2% inflation, from which point the effect becomes negative. Much alike, López-Villavicencio and Mignon (2011) focus on non-linearity and find that inflation starts to be detrimental to growth after exceeding approximately the annual rate of 2.7%, while it is conducive to growth below this level. However, López-Villavicencio's and Mignon's article uses postwar data sets that contain very few deflation episodes, and thus the results compare rather low and high inflation than inflation and deflation. Eichengreen, Park and Shin (2016) are an interesting study in that the authors replicate the data set and most of the methods of Borio et al. (2015), but complement CPI price series with PPI price series. They argue that especially in East Asia in the past few decades, deflationary pressures have demonstrated themselves more in producer prices than in consumer prices, so that more observations of deflation (and particularly persistent deflations) can be found in producer prices. They find out that when using PPI instead of CPI, the deflation-recession link is not limited to the Great Depression and interwar years, as Borio et al. (2015) suggest, but extends to other subsamples including the post-World War II subsample. Although their results are statistically significant across many subsamples and specifications, the economic significance is again rather low: in their baseline specification for all data, an increase in the inflation rate (both CPI and PPI) of 1 percentage point implies only a 0.1 percentage point increase in the growth rate of GDP per capita.

In recent years, some researchers have focused on the link between expected inflation (or deflation) and consumption. Interestingly, they have yielded starkly different results. Bachmann, Berg and Sims (2015), using recent data on the US economy, reject the hypothesis that the expectation of deflation leads to lower present consumption. By contrast, Hori and Shimizutani (2005) and Ichiue and Nishiguchi (2014) support this hypothesis using survey data on Japan. Davis (2015) analyzed inflation expectations and purchases by consumers in interwar years in the United States and found mixed results: the expectation of deflation impacted negatively durable goods purchases, but did not impact grocery store purchases. In addition, the coefficient estimates of the effect of inflation on durable goods purchases were relatively small (at most 0.22) when compared to the depth of the Great Depression included in the interwar sample.

Table 2.1: Summary of empirical literature (ordered by year of publication)

Study	Countries	Years	Main method	Deflation-recession link
		GDP growth and inflation		
Barro (1995)	International (100)	1960–1990	Pooled 10-year avrgs.	None
McCandless & Weber (1995)	International (110)	1960–1990	Corr. of avrg. rates	None
Gylfason & Herbertsson (2001)	International (170)	1960–1992	Random eff., annual data	None
Bordo & Redish (2003)	US, Canada	1870–1913	VAR, annual data	Weak
Bordo, Lane & Redish (2004)	US, UK, Germany	1880–1896	VAR, annual data	Weak
Borio & Filardo (2004)	International (10)	19th cent.–2002	Pooled 5-year avrgs.	Mixed
Atkeson & Kehoe (2004)	International (17)	19th cent.–2000	Pooled 5-year avrgs.	None/weak
Guerrero & Parker (2006)	International (15, 94)	19th cent.–2000	Fixed eff., annual data	Strong
Beckworth (2007)	US	1864–1897	VAR, annual data	Weak
Benhabib & Spiegel (2009)	International (17)	19th cent.–2000	Pooled 5-year avrgs.	Strong
López-Villavicencio & Mignon (2011)	International (44)	1961–2007	GMM, annual data	Strong
Borio et al. (2015)	International (38)	1870–2013	Pooled T-year avrgs.	None
Eichengreen, Park & Shin (2016)	International (38)	1870–2013	Fixed eff., annual data	Strong
		Consumption growth and inflation or inflation expectations		
Cargill & Parker (2004a)	Japan, US	1929–2002	OLS, annual data	Strong
Hori & Shimizutani (2005)	Japan	2001–2004	OLS/FE/RE, quart. data	Strong
Ichiue & Nishiguchi (2014)	Japan	2006–2013	Probit, quart. data	Strong
Bachmann, Berg & Sims (2015)	US	1984–2012	Probit, monthly data	None
Davis (2015)	US	1919–1939	OLS, monthly data	Weak

Finally, Cargill and Parker (2004a) found a negative effect on consumption growth of the switch of the economy from inflation to deflation, especially in a sample including the Great Depression in the United States.

Several other studies are difficult to classify among those in Table 2.1. Kaza (2006) points out that according to the NBER chronology of expansions and recessions in the United States, deflation tended to appear in the very early stages of expansions rather than early stages of recessions. He therefore doubts the causality chain from deflation to recession.[25] King (1994) empirically investigates Irving Fisher's debt-deflation theory on samples of countries in the Great Depression and in the early 1990s recession. He finds that the magnitude of the slump is correlated with the preceding increase in private debt. His work does not present a clear-cut opinion on deflation: on one hand, he gives merit to Fisher's debt deflation theory; on the other, he identifies the preceding increases in debt as the driving force of the debt-deflation mechanism.[26]

2.5 Summary in the AS-AD Framework and Scope for Empirical Research

Deflation in standard AS-AD

Having described the theories as well as evidence on the deflation-recession link in the previous sections, the key question is what is the desired direction of further empirical research and where are its limitations. For this purpose, I systematize the theories in a standard and extended aggregate supply-aggregate demand (AS-AD) framework and its dynamic version DAS-DAD. This allows us to show the major gaps in research and room for improvement. The current standard—as per Mankiw (2016), for example—is that the building elements of the AS-AD framework are (1) an IS equation, (2) the Taylor rule or another monetary-policy rule, (3) the New Keynesian Phillips curve, and (4) the Fisher equation. Elements (1), (2) and (4) make up a downward-sloping AD curve and element (3) constitutes an upward-sloping AS curve.

The basic AS-AD framework offers two obvious mechanisms of deflation: a drop in the price level can occur either as a result of the short-run AS curve expanding and shifting to the right (alone or together with its long-run variant, i.e. potential output $\overline{Y}$, and not being accompanied by an expansion of AD), or as a result of the AD curve contracting and shifting to the left, of course without a coincidental offsetting move of the AS. The two theoretical streams described above in Section 2.3 differ in that the former stresses the propagation of deflation once it occurs while the latter stresses its sources. Nevertheless, neither denies the two possible—supply and demand—origins of deflation.

[25] This assertion runs counter Guerrero and Parker (2006) who found a lagged negative effect of deflation on growth. However, Kaza dealt only with the US economy while Guerrero and Parker used a panel of countries, so the results are difficult to compare.

[26] Smith (2006) provides a summary of empirical evidence on deflation and growth, although it does not contain some of the most recent works. For Czech readers, Kovanda and Komrska (2017) provide a very recent summary of the most important empirical works on deflation.

Separating types of deflation

In assessing whether there is a link between deflation and output growth, it is essential to empirically separate the supply and demand sources, to the extent that data limitations allow it. In other words, deflation may show different correlations with output growth depending on periods and countries, but these correlations may only be accompanying effects of, say, shifts in nominal demand or changes in production costs. Yet, the more interesting question might be whether there are other effects of deflation on output growth—that is, effects of price deflation per se, beyond those that we can account for by shifts in the money supply or changes in production costs. The arguments on the deflation-recession link laid out in Section 2.3 essentially state that deflation may have the capacity to perpetuate itself. As a result, if these arguments also state that the effect of deflation on output growth is negative, then they imply that deflation may have more adverse effects on output than the initial effect caused by, for instance, a drop in money supply.

To give an example, a monetary contraction decreases aggregate demand which, in line with the AS-AD framework, leads to a drop of both output and prices in the short run as the economy moves down along the AS curve. This is the *initial* effect where output decreases primarily because of the monetary contraction and the drop in prices is a necessary adjustment, not a primary driving force. Mankiw (2001) argues that the downward-sloping shape of the AS curve does not necessarily imply whether a fall in output leads to a fall in prices or vice versa. Instead, output and prices may only be both reacting to a drop in the money supply. This underlines the need to empirically control for variables that may shift the AD and AS curves, so that we do not ascribe to inflation and deflation correlations that in fact belong to the money supply or other factors.[27]

However, some theories see secondary effects of deflation. Current deflation may lead to expectations that it will continue, which may cause postponement of spending. This postponed spending further depresses prices and, as the theory goes, may further deepen expectations of deflation. The key aspect is that if this 'spiral' is valid, the ongoing drops in aggregate demand and in output are no longer caused by the the initial monetary contraction but by the secondary effects of deflation. Therefore, these two phases should be empirically separated.

Another example of the need to separate 'initial' and 'secondary' deflation has arisen in recent years. The experience with repeatedly low inflation and low interest rates in developed countries has moved to the forefront the special possibility of zero-lower bound that is closely related to deflation. This was mentioned in the theoretical discussion in Section 2.3 and it has important implications for empirical research. Consider the DAS-DAD diagram with a non-standard DAD curve in Figure 2.2. The upward-sloping segment of the DAD curve is

[27] In an overview of theories on the Phillips curve (or, indirectly, the AS curve), Mankiw (2001) asserts that some hypotheses that have attempted to theoretically underpin the Phillips curve do not insist on a one-way direction of causation. Speaking of the Phillips curve, Mankiw (2001, p. 46) writes: "The inflation-unemployment tradeoff is, at its heart, a statement about the effects of monetary policy. It is the claim that changes in monetary policy push these two variables in opposite directions." This statement can be applied to the present text. Section 2.3 presented theories that see causality going from price changes to output growth. But the Phillips curve in its original form by Phillips (1958) rather suggested that unemployment (i.e., output) affects the rate of inflation, not the other way around. Therefore, the downward-sloping AS curve, which implies a positive correlation of output growth and inflation when money supply changes, can accommodate both views on causality.

referred to as 'kinked' by some authors (e.g., Buttet and Roy, 2014) and captures the potential effects of a floor on the nominal interest rate. As long as this floor is not binding, decreases in inflation can be offset by reductions in the nominal interest rate by the central bank, so that the real interest rates stays unchanged. When the floor becomes binding, however, decreases in the inflation rate start directly translating into increases of the real interest rate (as per the Fisher equation), which in turn reduces investment, consumption and output. This is why in the dynamic setting, even the aggregate-demand relationship between inflation and output becomes positive.[28]

The major message of the atypical DAD curve in Figure 2.2 is that there arises a possibility of an unstable equilibrium—or a deflationary spiral—that even adjustments of the DAS curve cannot offset. The standard case would be equilibrium S in Figure 2.2 where the curves have the expected shapes. Assuming adaptive expectations, this equilibrium is stable since short-run moves outside the equilibrium are followed by adjustments in DAS as economic agents update their inflation expectations according to actual inflation. When DAS_2 applies, the economy is already on the 'kinked' part of the DAD, but it will still revert to the stable equilibrium S since the DAS will adjust up and left (actual inflation exceeds expected inflation). However, point D is an unstable equilibrium: any move along the DAD down and left from D will induce the DAS to adjust by shifting down, since actual inflation is below expected inflation. This will further reduce inflation expectations and shift DAS still further down, and so on.

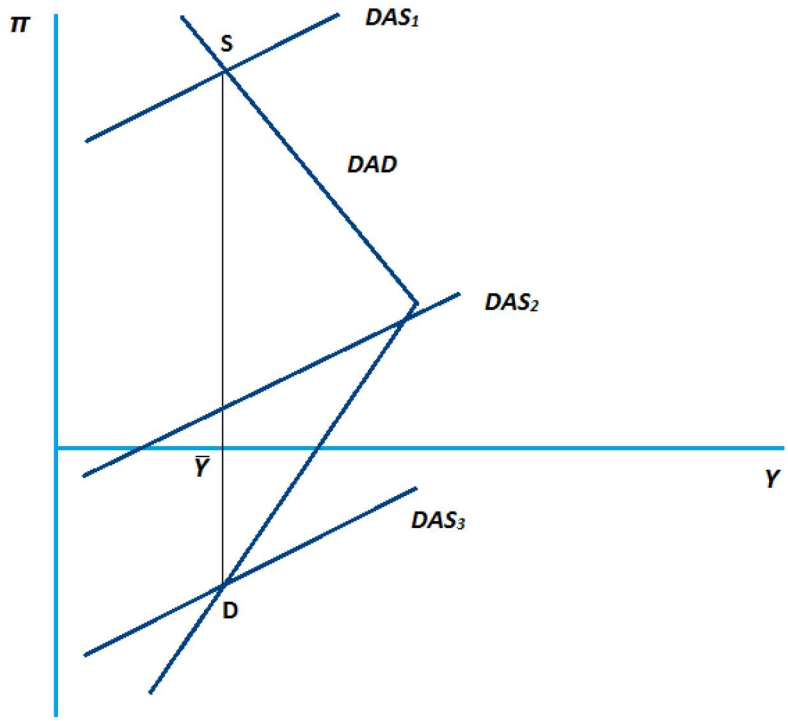
The surprising and counterintuitive implication of this hypothesis is that even positive supply shocks such as drops in world commodity prices may start an undesired deflationary spiral if the economy operates under the zero lower bound. This example in fact illustrates well the nature of some of the deflation-recession arguments by DeLong and Summers (1986) or Krugman (1998) described in Section 2.3: the primary trigger of deflation is much less important than its capacity to propagate and perpetuate itself. In the present extreme example, even a positive aggregate supply shock may trigger a deflationary spiral negative for output if deflation fully translates into the real interest rate. For empirical purposes, this again means that there could be a statistical relationship between deflation and output growth which is not reflected only in changes in the money supply, costs of production and other observable demand and supply factors. Deflation and output growth could have a relationship only 'on their own'.

Room for empirical research

It is these potential secondary effects of deflation, which may work independently of standard demand and output factors, that seem theoretically the most interesting, yet empirically little explored. As shown in the survey of empirical literature in Section 2.4, very few of the existing empirical studies try to separate these effects and determine whether there is a deflation-output link stemming from price deflation itself and not other factors. For example, one of the most

[28] This situation could be thought of as a sort of mirror opposite to the 1970s. Then, monetary authorities in the developed countries faced growing inflation but probably did not increase nominal interest rates enough. As a result, real interest rates dropped, causing output and mainly inflation to increase. The situation repeated itself. In the logic of the current example, the monetary authority does not do the opposite (because it cannot)—reduce nominal interest rates enough. As a result, real interest rates increase, causing output and inflation to fall further, and the situation repeats itself. I thank Pavel Potužák for pointing out this comparison.

Figure 2.2: DAS-DAD: A 'kinked' dynamic aggregate demand curve



Note: Based on Buttet and Roy (2014) and Mankiw (2016); own adaptation.

cited studies, Atkeson and Kehoe (2004), looks only into simple regressions of output growth on inflation. Guerrero and Parker (2006) and Benhabib and Spiegel (2009 extend this work in an econometric sense (panel data methods, non-linearities) but do not add other variables.

Borio et al. (2015) are a partial exception as they add two types of additional variables. First, they add further *price* variables such as house prices and stock prices. Inclusion of these variables is important and helps broaden the perspective from consumer prices to processes in the financial system, but these variables may again act as symptoms of shifts in demand factors rather than represent a primary driving force. Second, the authors add debt measures and also the deviation of credit-to-GDP from its long-run trend. Again, these variables serve as proxies for the creation of financial excesses, but arguably the deviation of credit-to-GDP from its long-run trend can be thought of as a demand variable. However, the authors include no supply-side variables. Finally, Bordo and Redish (2003) and Bordo, Lane and Redish (2004) use data on money supply in their VAR models to account for the effects of nominal demand on output and prices. However, their work is limited to pre-World War I data and only three countries. The lack of use of control variables in most works may be understandable given the fact that data on prices and output are obtainable more easily than data on any other control variable. However, the data set in the present work is relatively rich also in other variables.

Therefore, the present work aims to at least partly fill this gap. Given the data constraints

especially for the older periods, the choice of control variables is rather straightforward. To control for nominal demand, I use data on money supply, and to control for costs on the supply side, I use world prices of oil. These two variables obviously cannot account for all shifts of aggregate demand and aggregate supply. Especially changes in aggregate demand may have various sources: autonomous drops in consumption or investments spending, reduction of government expenditures, drops in exports or a monetary contraction. However, as a practical issue, there are no other variables as generally available as these two.

The mentioned studies have several further drawbacks worth mentioning.

Atkeson and Kehoe (2004) and Benhabib and Spiegel (2009) explore relatively long datasets but use 5-year average growth rates of GDP and prices as the input for their regressions. This approach may have a double disadvantage. For one thing, it misses some of the short-term variation in prices and output as this variation is lost by averaging.[29] But the 5-year averaging also precludes the revelation of longer-run association between output and prices. Guerrero and Parker (2006) capture the short-run variation by using yearly observations but they rely only on one-year lagged effect of prices on output. This approach may be too restrictive because it assumes that the effect can only last precisely 1 year, while the series that Guerrero and Parker use lasts more then 100 years and may contain longer-term associations.

In the following chapter, I aim to fill these gaps of the existing research. I include money supply and oil prices as control variables and I use both short-run and long-run methods to investigate the inflation-growth link.

[29] There is also a certain amount of arbitrariness in choosing in which initial year the 5-year averages start.

Chapter 3

Macroeconomic Approach to Deflation

3.1 Motivation

The previous chapter has shown that the current empirical research on deflation has the disadvantage of not controlling for both demand and supply factors in judging the link between price inflation and economic growth. Also, research pieces usually focus on contemporaneous correlation or average observations over medium term and lack long-run methods.

The present chapter aims to fill this gap and provide a more comprehensive look at what we know about the relationship between deflation and economic growth over the long run. To do so, I have assembled a large dataset that contains annual data on output and prices for 20 countries over the past 130–200 years. Thanks to the length of the time series, it is possible to draw valuable information from pre-World War I data which are rich in episodes of deflation. The goal of this chapter is to find out whether deflation is associated with recession—after controlling for demand and supply factors—when taking into account long-run empirical evidence.

The chapter proceeds as follows. In Section 3.2, I present the macroeconomic data set used in this chapter and show basic properties of output growth and price growth in the sample. Section 3.3 provides relatively extensive descriptive statistics of GDP growth and price growth, with an overview of certain historical episodes and and special focus on mild inflation and deflation. I then use econometric methods in Section 3.4 to see whether changes in prices have an effect on changes in output, controlling for money supply on the demand side and oil prices on the supply side. This section first uses the VAR/VECM methods, pays special attention to the Great Depression and Japan and then provides comparison in ARDL and Fixed Effects models to compare and discuss the results. Section 3.5 summarizes the findings of the chapter.

3.2 Data

I have compiled a large historical data set with annual observations on prices and output comprising 20 countries. Output is measured as real GDP and prices are represented by the

Descriptive statistics and some single-equation results from this chapter were published as Ryska, P. (2017): Deflation and Economic Growth: The Great Depression as the Great Outlier, *Quarterly Journal of Austrian Economics*, 20(2): 29–61. Results including VAR and VECM models have been submitted to *Prague Economic Papers* as Ryska, P.: Deflation and Economic Growth in Long-Term Perspective.

Consumer Price Index or the GDP Deflator.[1] A detailed description of variables and their sources is given in Appendix 3.A and the length of each times series in Appendix 3.B.[2] As control variables, I use real consumption, money supply, the oil price and level of economic development. These further variables are discussed more in Section 3.4 that presents regressions. The data set consists of 20 countries and spans from the 19th century to 2015. To give a glimpse of the length of the time series, the earliest observations on prices start as early as 1804 for Sweden and the US. Most countries, however, have records on prices that begin several decades later. Altogether, there are 3293 annual observations that have both a reading for price growth and output growth.

Below for basic statistics, I present the data set in two forms. First, I use the complete dataset, and second, a truncated dataset where I leave out observations with extreme values of price growth. The reason is that the main question of interest is how economies perform under reasonably 'normal' inflation rates compared to 'normal' deflation rates. Leaving hyperinflations as well as extremely deep deflations in the sample would severely bias the regression results and would not help answer the question whether mild inflation is preferable to mild deflation. I exclude all years with price growth greater than 20% or lower than -20%.[3]

3.3 Descriptive Statistics

3.3.1 Full Sample

In the entire sample, positive price growth prevails, with years that saw positive inflation accounting for 72% of all annual observations. Inflation rates between 2 and 4% are the most frequent observations as shown in the top chart of Figure 3.1. This prevalence of inflation over deflation in the sample mostly reflects the generally inflationary post-World War II period which saw only sporadic deflation. However, thanks to the inclusion of the pre-World War I data, deflation is far from infrequent and allows a comparison of output performance under inflation and deflation.

The two bottom charts in Figure 3.1 illustrate the major difference in the behavior of the price level before and after World War I. Under the classical gold standard, which was in place in most countries until roughly 1914, very mild deflation of 0 to -2% was the most common observation. After the abandonment of the classical gold standard, the average inflation rate shot up and positive inflation became the standard.[4]

[1] The reason for the use of both indices is availability. I use the Consumer Price Index where possible since it is today the generally preferred measure of inflation by most economists and organizations. I use the GDP deflator where the CPI is unavailable, which is true particularly for the older observations. It is generally possible to retrieve very long times series on prices such as from Reinhart and Rogoff (2011), which span back to the 18th century, but these are based on narrow baskets or individual goods' prices, not on broad indices. Here, I only use CPI or the GDP deflator.

[2] The countries included are Argentina, Australia, Belgium, Brazil, Canada, Chile, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.

[3] The choice of such a boundary is necessarily arbitrary. I follow Atkeson and Kehoe (2004), Ichiue and Nishiguchi (2014) and Bachmann et al. (2015) who all use the 20% and -20% thresholds. A 20% inflation is roughly the one that developed economies reached at the height of inflation in the late 1970s and early 1980s.

[4] The term classical gold standard denotes what was in most countries the period from approximately the

Figure 3.1: Inflation: histograms

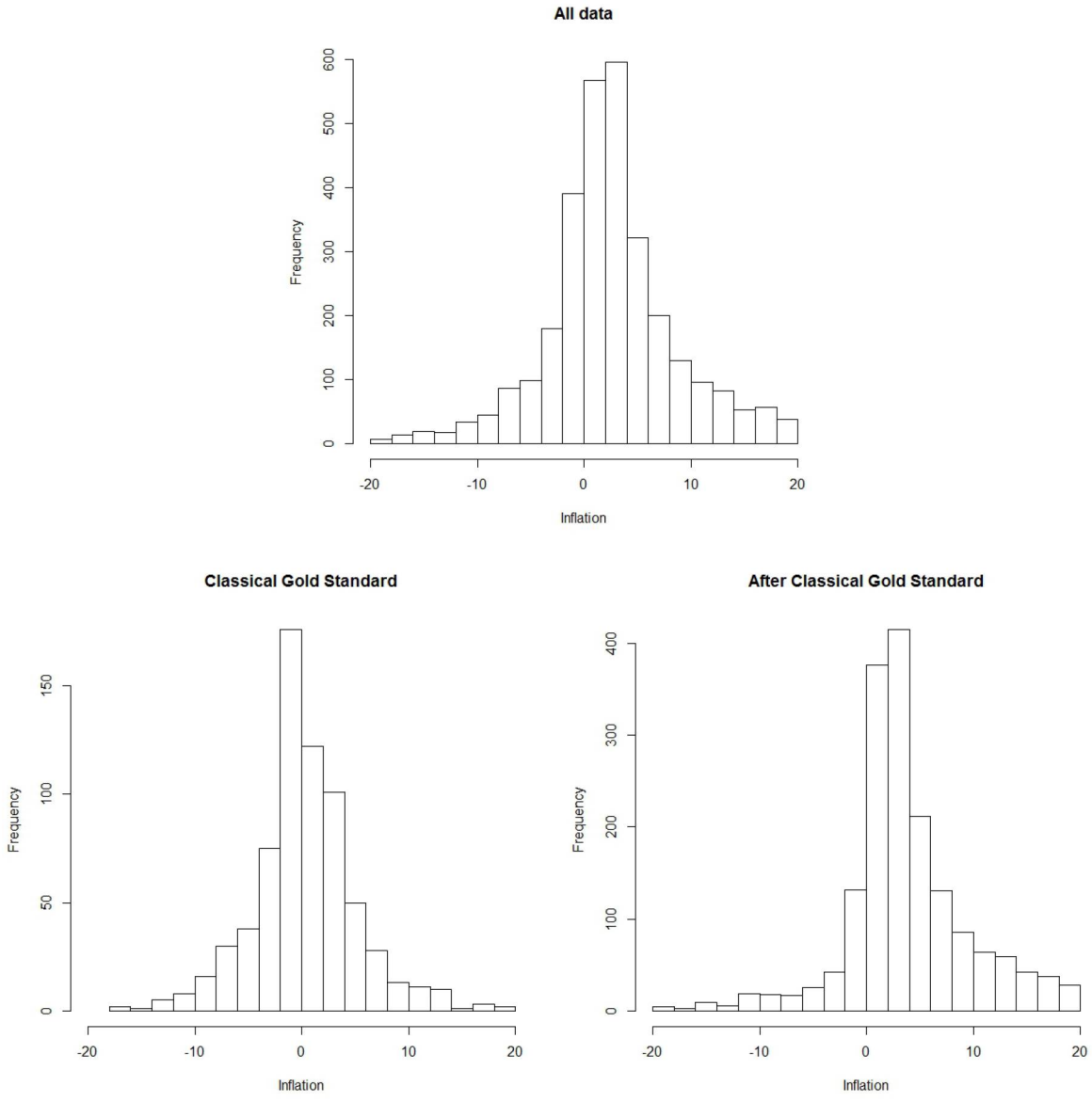


Table 3.1 compares economic growth under inflation and deflation.[5] There are several important observations. First, economic growth was positive in 81.1% of years with inflation and in 74.8% of years with deflation. While this preliminary observation shows that deflation has not been associated with recession on average, economies still seem to fare a bit better under inflation. A second and more meaningful approach is to compare the average growth rate of output. Under inflation, output grew 2.85% per year on average, while under deflation the growth rate was 2.73%. Again, this suggests that the output loss of having deflation instead of inflation is very small. Third, output growth appears to be slightly less volatile under inflation than under deflation, as measured by standard deviations.

To test whether the observed differences of output behaviour are statistically significant, in Table 3.2 I present formal tests of equality of parameters. Interestingly, it is not possible to reject the null hypothesis (at any standard significance level) that the average output growth rates under inflation and deflation are equal. Similarly, the variances are not statistically different either. To sum up, there is no statistically significant difference in the average growth rate of output or in the variance of output growth under inflation versus deflation.

Tables 3.3 and 3.4 report the same computations, but now with the sample reduced to contain only inflation rates in the interval [-20%, 20%]. The results suggest that this limitation works in favor of inflation: a slightly higher percentage of inflationary observations now have output increase and also the average output growth under inflation increases to 2.97%. Similarly, the variance of growth under inflation drops significantly.

This shift is has an explanation. Hyperinflations and very fast inflations are harmful to economic growth and also cause its higher volatility. As a result, leaving these extreme values out of the sample helps the statistical properties of growth under inflation. By contrast, growth under deflation does not profit from this truncation. The reason is also apparent: very deep deflations below -20% rarely occur under 'normal' conditions; instead, they appear often as a reversal of wartime inflations. Therefore, growth under these extreme deflations is often solid since it reflects post-war recoveries. This is the reason why leaving out extreme deflations leads to a slightly lower average output growth under deflation. However, the statistical tests again fail to reject the hypothesis that the two output growth rates are equal (Table 3.4). In other words, given the size of the samples and the variation in observations, the two rates of output growth are very similar. Only the variances are confirmed to be different.

Overall, using all available observations, economic performance seems to be very similar under inflation and deflation. Even when extreme observations are omitted from the sample, which 'helps' growth under inflation, economic performances under the two price regimes are still very comparable.

3.3.2 Selected Episodes

Table 3.5 breaks down the comparison of GDP growth under inflation and deflation into various periods and episodes of interest. This comparison is then depicted in Figure 3.2. Episodes

1870s until the beginning of World War I. The later forms of gold standard did not guarantee full convertibility of currency into gold.

[5] 'Zero price change' is included in Table 3.1 as there are observations, though not many, with exactly zero reported inflation. This is due to rounding of the index in the original data source.

Table 3.1: Output growth under inflation and deflation (all data)

	All data	Inflation	Zero price change	Deflation
Total observations	3293	2387	106	800
– obs. with output increase	79.6%	81.1%	84.0%	74.8%
– obs. with output unchanged	0.4%	0.3%	0%	0.6%
– obs. with output decrease	20.0%	18.6%	16.0%	24.6%
Average output growth	2.85	2.85	3.52	2.73
Output growth st. deviation	5.59	5.58	4.69	5.74

Table 3.2: Tests of equality of parameters: Inflation vs. deflation (all data)

	Test statistic	p-value
T-test for equality of means	−0.507	0.612
F-test for equality of variances	1.059	0.158

Null hypotheses: Means (variances) of output growth under inflation and deflation are equal.
Welch unpaired and two-sided t-test used for means, F-test used for variances.
* denotes statistical significance at 10%, ** at 5% and *** at 1% level.

Table 3.3: Output growth under inflation and deflation (price growth narrowed to [-20%, 20%])

	All data	Inflation	Zero price change	Deflation
Total observations	3029	2141	106	782
– obs. with output increase	80.9%	83.0%	84.0%	74.7%
– obs. with output unchanged	0.4%	0.3%	0%	0.6%
– obs. with output decrease	18.7%	16.7%	16%	24.7%
Average output growth	2.90	2.97	3.52	2.63
Output growth st. deviation	4.95	4.70	4.69	5.58

Table 3.4: Tests of equality of parameters: Inflation vs. deflation (price growth narrowed to [-20%, 20%])

	Test statistic	p-value
T-test for equality of means	−1.505	0.132
F-test for equality of variances	1.411***	< 0.001

Null hypotheses: Means (variances) of output growth under inflation and deflation are equal.
Welch unpaired and two-sided t-test used for means, F-test used for variances.

located on the 45-degree line have the same average growth rate of output in years with inflation

as in years with deflation. Episodes to the right of the line have better growth under inflation, while episodes to the left of the line under deflation.

The comparison of the classical gold standard period and the post-classical gold standard period reveals a major difference. While under the metallic monetary regime output growth was almost identical under inflation and deflation, it started to differ significantly after the shift to fiat money regimes or partial gold standard which occurred after World War I. However, an even starker difference shows up when one singles out the Great Depression (1929–1934). This period is the only one in the whole sample that shows negative GDP growth under deflation (-1.13%) and very quick growth under inflation (4.66%), the difference being highly statistically significant. No other period in the sample displays such divergence.

An even more interesting result is for the whole sample except Great Depression: it shows mean GDP growth being slightly *higher* for deflation than for inflation. This illustrates how much the relatively short Great Depression affects the whole sample. Although the Great Depression represents less than 5% of data points in the whole sample ('All data'), its values are so different that it is able to move 'All data' to the right of the 45-degree line. Excluding the Great Depression, the sample lies slightly to the left of the line. Similarly, the post-World War II subsample ('Postwar') shows virtually identical GDP growth for inflation and deflation as it does not contain the Great Depression.

Interestingly, the picture changes after 1990. Here, GDP growth is clearly faster with inflation than with deflation. What could be the reason for the different result after 1990 compared to the postwar (1946–2015) result? Western countries went through repeated deflations in the late 1940s and in the 1950s when they experienced fast growth. Later, however, deflation became very infrequent and after 1990 it appeared basically in only three circumstances: in the worldwide economic crisis of 2009, in Japan starting in the 1990s and during the default of Argentina around 2000. In all of these cases, slow or negative growth was measured, which leads to a poor result for deflation. Therefore, this is reflected in the period 1991–2015, while it is offset by strong growth under deflation in the early parts of the period 1946–2015. This explains the very different results for periods 1991–2015 and 1946–2015 in Table 3.5 and in Figure 3.2.

Since the 1990s, Japan has become a synonym for a deflation-haunted country. Yet, Table 3.5 shows that growth was not significantly different under inflation and deflation in the period 1991–2015. I also include the shorter period 1995–2015 because it was not until 1995 that annual deflation first appeared in Japan. Surprisingly, in this period GDP growth was *exactly* the same under inflation and deflation.

Overall, the general picture from descriptive statistics does not support the hypothesis that deflation is linked to significantly subpar growth, let alone recession. The key observation is that deflation was linked to recession only in the specific period of the Great Depression in 1929–1934, but in no other period.

A cautionary note is due, however. The statistical relationships say nothing about causation and only provide links between two variables with no controls. More extensive analysis will be performed in regressions in Section 3.4.[6]

[6] A remark is due concerning the higher standard deviation of output growth under deflation than under inflation in Table 3.1. As much more deflation was recorded in the 19th century than in recent times, there

Table 3.5: Output growth under inflation and deflation in selected episodes

	Mean GDP growth			Percent of obs. with GDP growth > 0	
	Inflation	Deflation	t-test: p-value	Inflation	Deflation
All data	2.97	2.63	0.132	83.0%	74.7%
Classical gold standard	2.74	2.64	0.787	80.1%	79.0%
After classical gold standard	3.25	2.00	0.007***	86.9%	66.7%
Great Depression	4.66	−1.13	< 0.001***	76.7%	44.3%
All data ex-Great Depression	2.95	3.06	0.628	83.1%	78.1%
Postwar (1946–2015)	3.41	3.43	0.612	90.7%	76.1%
Recent (1991–2015)	2.17	0.17	< 0.001***	86.8%	62.5%
Japan 1991–2015	1.07	0.90	0.837	84.6%	75.0%
Japan 1995–2015	0.90	0.90	0.999	77.8%	75.0%

Welch unpaired and two-sided t-test used. Null hypothesis: Means of output growth under inflation and deflation are equal.
Years where inflation is outside [-20%, 20%] annual change are excluded.

3.3.3 Mild Inflation vs. Mild Deflation and the Zero Lower Bound

Restricting price growth to the interval [-20%, 20%] ensures 'reasonable' rates of inflation that have prevailed in the past several decades. However, even inflation or deflation in excess of approximately 5% in absolute value is nowadays scarce in most advanced economies. In addition, very few economists would call for inflation in excess of higher single digits.

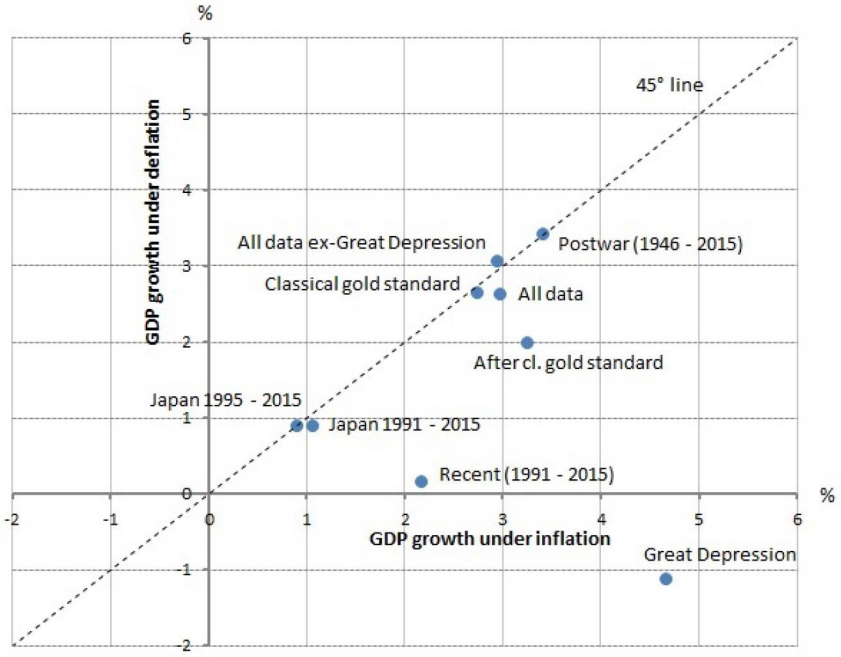
This prevailing view is best represented by central banks' inflation targets. Most of them currently stand at or near 2%. The US Federal Reserve has 2% inflation as its long-run target (Federal Reserve, 2012), the European Central Bank aims for 'inflation rates of below, but close to, 2%' in the medium term (ECB, 2017) and, similarly, the Czech National Bank targets 2% inflation with deviations of up to 1 percentage point on both sides (CNB, 2017). A full account of the reasoning behind the 2% inflation target would be outside the scope of this text.[7] However, there are two qualitative arguments that are often mentioned as intuitive reasons for keeping inflation above zero.

First, measured inflation is likely overstated. The most currently used measure of inflation is the CPI, which is a Laspeyeres-type index and as such disregards the substitution by consumers from more expensive to cheaper items in the consumer basket. Therefore, reported inflation is higher than actual inflation. Estimates of the overstatement of inflation differ. For example, Plosser (2003) cites an overestimation of 1 percentage point, while Feldstein (2002) considers it to be bigger, possibly up to 2 percentage points. As a result, the setting of a 2% inflation

is the possibility that the higher standard deviation of growth during deflation is caused by the imprecision of measurement for the older observations. There was no systematic measurement of GDP, GDP deflator or broad consumer price indices in the 19th century. The series were not measured, but rather estimated from other series such as industrial production, agricultural production and wholesale price indices, which are themselves typically more volatile. This could add to the volatility of the derived series. I thank an anonymous referee for pointing this out.

[7] See Diercks (2017) for a list of studies on optimal inflation and the reasoning behind their results.

Figure 3.2: Output growth under years with inflation and deflation in selected episodes



target may just reflect this overestimation, so that if this target is met, true inflation will be somewhere between 0 and 1 percent.

Second, the choice of positive inflation as target may reflect a precautionary principle in monetary policy. The US Federal Reserve explains that "having at least a small level of inflation makes it less likely that the economy will experience harmful deflation if economic conditions weaken" (Federal Reserve, 2015). In other words, some small positive inflation provides a buffer against deflation if deflation is thought to be harmful for economic growth. This second argument is key because it assumes that mild inflation is on average preferable to mild deflation. If the inflation target was zero, the argument goes, then a deviation to, say, -2% would be worse for the economy than a deviation to +2%. The large data set on hand makes it possible to test such hypotheses.

Since the most common inflation target is approximately +2%, I have singled out four inflation and deflation intervals, namely (-4%, -2%), (-2%, 0%), (0%, 2%) and (2%, 4%), and computed the features of output growth associated with them. The intervals do not include border points so as to avoid the bias from their asymmetric inclusion in one or another interval. The results are presented in the top part of Table 3.6 and are visualized in Figure 3.3. One clear observation is that the average growth rate of output in any of the intervals is not dramatically different from the others. All four intervals are associated with distinct economic growth, which mirrors the finding in Table 3.1 that growth under deflation is not markedly different from that under inflation. However, the inflation interval (2%, 4%) does seem to have a higher growth rate of output, just as it has a lower standard deviation of output growth.

Formal tests of equality of means and standard deviations in Table 3.6 provide cross com-

parisons of all pairs of the intervals. None of the intervals is proven to have statistically better output growth than others. Interestingly, the seemingly higher output growth rate in the interval (2%, 4%) is not statistically different from the others as the p-value of the t-test is above any standard level of significance. In contrast, F-tests show that the standard deviation of output growth in the (2%, 4%) interval is indeed smaller compared to the others. Overall, if the main criterion is the pace of economic growth, it does not appear that mild-inflation intervals are superior to mild-deflation ones. This empirical conclusion seems to be consistent with a recent comprehensive survey of works on optimal inflation by Diercks (2017). He finds that out of 100 studies since the mid-1990s that have given quantitative values of optimal inflation, only about 20 have determined a positive inflation rate. Most studies place optimal inflation at 0% or very close to it. A caveat for the present finding is the time span of the sample. Older observations may not represent today's regularities.

Table 3.6: Output growth under inflation intervals: mean, standard deviation and tests

Output growth: average rate and standard deviation

Intervals of inflation	(-4%, -2%)	(-2%, 0%)	(0%, 2%)	(2%, 4%)
Average output growth	2.66	2.64	2.73	3.03
Output growth st. deviation	4.44	4.45	4.16	3.86
Observations	177	285	566	593

t-tests for equality of average output growth: matrix of p-values

Intervals of inflation	(-4%, -2%)	(-2%, 0%)	(0%, 2%)	(2%, 4%)
(-4%, -2%)	–	0.973	0.848	0.310
(-2%, 0%)	–	–	0.783	0.204
(0%, 2%)	–	–	–	0.199
(2%, 4%)	–	–	–	–

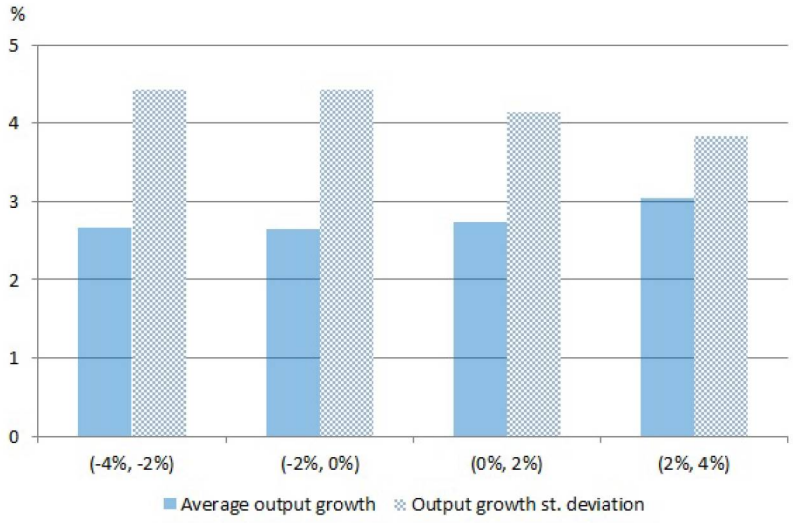
F-tests for equality of output growth standard deviation: matrix of p-values

Intervals of inflation	(-4%, -2%)	(-2%, 0%)	(0%, 2%)	(2%, 4%)
(-4%, -2%)	–	0.491	0.141	0.008***
(-2%, 0%)	–	–	0.097*	0.001***
(0%, 2%)	–	–	–	0.329**
(2%, 4%)	–	–	–	–

Null hypothesis: Means (variances) are equal. Welch unpaired and two-sided t-test used for means, F-test used for variances.

A more subtle argument, often used in monetary policy works, is that deflation is harmful mainly when the interest rate hits the zero lower bound. This reflects the idea that once the nominal interest rate reaches zero, it can no longer absorb falling inflation or outright deflation, and so the real interest rate rises, dampening current consumption and investment (e.g. Krugman, 1998, or Kuroda, 2016). There are two obstacles when analyzing the zero lower bound empirically. First, its occurrence has been rare historically and most observations are from the past decade. Second, the availability of historical data on the short-term interest rate

Figure 3.3: Output growth under inflation intervals: mean and standard deviation



is poorer than on prices or output, so that the determination of when zero lower bound occurred is sometimes impossible.

To obtain a reasonable number of observations, I define the zero lower bound more broadly as observations when the short-term interest rate was less than or equal to 1%. There are only 181 such observations out of the total 3293 where the zero-lower bound can be identified and where this condition holds. Out of these 181 observations, 94 are after the year 2007. This illustrates that the zero-lower bound is empirically heavily skewed towards the present and, moreover, that more than half of the observations fall into the current post-crisis, low-growth environment.

The key question is whether deflation is especially harmful under the zero lower bound. With zero lower bound binding, output growth under deflation is on average 1.2% while under inflation 2.1%. However, the t-test of equality of means shows a p-value of 0.082, a rather borderline reading. This may be due to a low number of observations and also due to higher standard deviation of output growth under inflation than under deflation (5.3 vs. 3.2). Data seem to show that inflation is more conducive for GDP growth under the zero lower bound, but a strong statistical confirmation is missing. Overall, the number of annual observations for zero lower bound is very small compared to the full sample in this work and therefore does not allow similarly detailed analysis.

3.4 Regression Analysis

3.4.1 Methods

Choice of Endogenous and Exogenous Variables

The choice of variables stems directly from the discussion of the DAS-DAD framework and of the goals of research laid out in Section 2.5. The main goal of regression analysis below is to

find whether there is an effect of price growth on output growth after controlling for some of the factors that likely shift the dynamic aggregate supply and demand curves. Therefore, the aim is to see whether there is a further link between price growth and GDP growth, independent of shifts in major demand and supply factors.

Real GDP Y and prices P are the two key variables. I also add real consumption C, which has become available for long historical data sets and which can enrich the understanding of the behaviour of real variables from the usual exclusive focus on real GDP. Given the quantitative equation of money in the Fisherian form $\mathsf{M} \cdot \mathsf{V} = \mathsf{P} \cdot \mathsf{Y}$, it is straightforward to choose money supply M as the control variable for demand.[8] The choice of a supply control variable is more difficult because our panel data set has 20 countries which differ by structure of production and, more importantly, the data set spans from roughly 1870 to 2015. Still, the oil price Oilp seems to be the best choice for two reasons. For one thing, it enters most sectors of production as a cost item. Second, it is available as far back as to the 1860s. Of course, the importance of oil prices for the pre-World War I period should not be overestimated. However, there is no other cost item that would be as universally important and as available for empirical work as the oil price. Finally, there could be concern that the sample of 20 countries over such a long period contains episodes of economic convergence which affect the rate of growth of output and prices. This concerns both developing countries in the sample (Argentina, Brazil, Chile) and cases of countries which are now considered advanced but were developing or 'catching up' over the course of the period covered in the data set. This could be for example the case of Japan after World War II which converged to the economic level of the United States and during this process showed faster growth of both GDP and prices. Eichengreen et al. (2016), for instance, add log of per capita GDP to account for the fact that the level of economic development may affect the rates of growth. Therefore, we add GDP per capita in USD $\mathsf{Ypercap}$ (in logs) as a control variable to capture the level of economic development of a given country in given year.

Some of the methods of choice are vector error-correction model (VECM) and autoregressive distributed lag model (ARDL) laid out below. An important question is which variables should be treated as endogenous and which as exogenous in the system. I treat real output, prices, consumption and money supply as endogenous. The first three of them are variables of interest which are logically treated as endogenous since the goal is to explore their interactions after innovations in each of them. Money supply is also treated as endogenous because it can react to other variables such as output growth or prices either by itself or by decisions of monetary policy. In contrast, I treat the oil price as exogenous. Although the oil price reacts to the development of real and monetary variables, for most of the countries in the sample it acts exogenously. One way of looking at the oil price is to regard it as a foreign price that the country in question cannot influence.[9] The measure of development, GDP per capita in US dollars, is also treated exogenously here since it is only used as a control variable. A short

[8] The exact measure of money supply differs country by country according to availability. See Appendices 3.A and 3.B to this chapter for details.

[9] Kim and Roubini (2000), for example, treat money supply as endogenous and the oil price as contemporaneously exogenous. Here, the oil price is treated as fully exogenous since it is assumed that the potential effect of price inflation on real GDP growth does not work through the world price of oil. In other words, while the price of oil surely affects GDP growth in most countries and therefore is part of the regressions, it is not affected by the domestic price inflation.

overview of variables used below is in Table 3.7. Small-case letters are used below to denote that the variable is used growth rates (or differences of logs).

Table 3.7: Overview of variables

Variable	Notation	Treatment	Enters VAR's in:
Real GDP	Y	Endogenous	Growth rates
Prices	P	Endogenous	Growth rates
Real consumption	C	Endogenous	Growth rates
Money supply	M	Endogenous	Growth rates
Oil price	Oilp	Exogenous	Growth rates
GDP per capita	Ypercap	Exogenous	Levels

For sources and availability of data see Appendices 3.A and 3.B to this chapter.

VAR and VECM

For samples with a long enough time dimension (tens of years in length), I explore long-term relationships between variables which encompass potential feedbacks. For this purpose, I use the vector autoregression (VAR) model or, where cointegration is indicated, the vector error correction model (VECM). The system of equations below regresses real output growth y, price growth p, real consumption growth c and money supply growth m on their own past values and on values of the exogenous variables. Impulse response functions are an attractive feature of the VAR/VECM analysis. These show how each variable reacts over time to a one-unit exogenous shock to any of the other variables. The impulse response functions are key in judging the long-term impact of one variable on another, while taking into account all feedbacks between the variables.

Following loosely Ender's (2015) presentation of VAR and VECM, consider the following system of three equations which has for simplicity only one lag of each macroeconomic variable among the regressors. In order not to complicate the equations too much, I leave out the two exogenous regressors and focus on the endogenous ones:

$$\mathsf{y}_{it} = \beta_{y0} + \beta_{y1}\mathsf{y}_{it-1} + \beta_{y2}\mathsf{p}_{it-1} + \beta_{y3}\mathsf{c}_{it-1} + \beta_{y4}\mathsf{m}_{it-1} + \epsilon^{y}_{it}$$

$$\mathsf{p}_{it} = \beta_{p0} + \beta_{p1}\mathsf{y}_{it-1} + \beta_{p2}\mathsf{p}_{it-1} + \beta_{p3}\mathsf{c}_{it-1} + \beta_{p4}\mathsf{m}_{it-1} + \epsilon^{p}_{it}$$

$$\mathsf{c}_{it} = \beta_{c0} + \beta_{c1}\mathsf{y}_{it-1} + \beta_{c2}\mathsf{p}_{it-1} + \beta_{c3}\mathsf{c}_{it-1} + \beta_{c4}\mathsf{m}_{it-1} + \epsilon^{c}_{it}$$

$$\mathsf{m}_{it} = \beta_{m0} + \beta_{m1}\mathsf{y}_{it-1} + \beta_{m2}\mathsf{p}_{it-1} + \beta_{m3}\mathsf{c}_{it-1} + \beta_{m4}\mathsf{m}_{it-1} + \epsilon^{m}_{it}$$

Variables y, p, c, m are the growth rates of real GDP, prices, real consumption and money supply, respectively (entered as differences of natural logs), subindices i and t stand for the given country and year, respectively, and ϵ is the error term. Such a system constitutes a

standard VAR which allows us to study the effects of GDP, prices, consumption and money supply on one another including feedbacks.

There is a possibility, however, that the underlying variables in levels Y, P, C and M are non-stationary and integrated, meaning that they move together in a common trend. In this case, the VAR model above does not fully describe the dynamics since the growth rates $\mathsf{y_{it}}$, $\mathsf{p_{it}}$, $\mathsf{c_{it}}$ and $\mathsf{m_{it}}$ may also be affected by the distance between the levels. Then, the system should be constructed as VECM instead:

$$\mathsf{y_{it}} = \beta_{y0} + \beta_{y1}\mathsf{y_{it-1}} + \beta_{y2}\mathsf{p_{it-1}} + \beta_{y3}\mathsf{c_{it-1}} + \gamma_y(\mathsf{Y_{it-1}} - \alpha_0 - \alpha_1\mathsf{P_{it-1}} - \alpha_2\mathsf{C_{it-1}} - \alpha_3\mathsf{M_{it-1}}) + \epsilon^y_{it}$$

$$\mathsf{p_{it}} = \beta_{p0} + \beta_{p1}\mathsf{y_{it-1}} + \beta_{p2}\mathsf{p_{it-1}} + \beta_{p3}\mathsf{c_{it-1}} + \gamma_p(\mathsf{Y_{it-1}} - \alpha_0 - \alpha_1\mathsf{P_{it-1}} - \alpha_2\mathsf{C_{it-1}} - \alpha_3\mathsf{M_{it-1}}) + \epsilon^p_{it}$$

$$\mathsf{c_{it}} = \beta_{c0} + \beta_{c1}\mathsf{y_{it-1}} + \beta_{c2}\mathsf{p_{it-1}} + \beta_{c3}\mathsf{c_{it-1}} + \gamma_c(\mathsf{Y_{it-1}} - \alpha_0 - \alpha_1\mathsf{P_{it-1}} - \alpha_2\mathsf{C_{it-1}} - \alpha_3\mathsf{M_{it-1}}) + \epsilon^c_{it}$$

$$\mathsf{m_{it}} = \beta_{m0} + \beta_{m1}\mathsf{y_{it-1}} + \beta_{m2}\mathsf{p_{it-1}} + \beta_{m3}\mathsf{c_{it-1}} + \gamma_m(\mathsf{Y_{it-1}} - \alpha_0 - \alpha_1\mathsf{P_{it-1}} - \alpha_2\mathsf{C_{it-1}} - \alpha_3\mathsf{M_{it-1}}) + \epsilon^m_{it}$$

The VECM adds the error-correction term in the brackets, which describes how the variables in levels converge in period t if they had a gap (or error) of magnitude $(\mathsf{Y_{it-1}} - \alpha_0 - \alpha_1\mathsf{P_{it-1}} - \alpha_2\mathsf{C_{it-1}} - \alpha_3\mathsf{M_{it-1}})$ between them in period $t-1$. γ is the speed of adjustment given the previous period's error between the levels. Therefore, γ tells us how much of the previous period's gap between the levels is closed in the current period for the given endogenous variable. If this process exists, error-correction is part of the change in regressands $\mathsf{y_{it}}$, $\mathsf{p_{it}}$, $\mathsf{c_{it}}$ and $\mathsf{m_{it}}$ and hence should be included in the equation. The addition of the error-correction term can also be described as an imposition of restriction on the underlying VAR model since cointegration assumes that the variables converge in the long run.

It turns out below that cointegration was in fact detected in all the samples studied, which is probably due to the length of the series and the long-run trends in GDP, prices, consumption and money supply.

Autoregressive distributed lag model

An alternative to the equation systems VAR and VECM is a one-equation autoregressive distributed lag model (ARDL) which can also accommodate the possibility of cointegration. Given the length of the data and its panel nature, one of the possible estimation techniques is the Pesaran-Shin-Smith Pooled Mean Group estimator. The key feature of the estimator is that it allows the short-run coefficients, intercepts and error-correction terms to differ in cross-sections (here countries), while it requires long-run effects to be the same. According to Shin, Pesaran and Smith (1998), the reason to use an estimator of this kind is that with larger time dimension T, other panel data estimation techniques such as generalized method of moments (GMM) or

fixed-effects estimators can be inconsistent in a dynamic setting if the slope coefficients are not the same in each cross-section.

An example of an ARDL model with one lag of each variable and in line with the variables in the above VAR and VECM is

$$\begin{aligned} \mathsf{y}_{\mathsf{it}} = \beta_0 + \beta_1 \mathsf{y}_{\mathsf{it}-1} + \beta_2 \mathsf{p}_{\mathsf{it}} + \beta_3 \mathsf{p}_{\mathsf{it}-1} + \beta_4 \mathsf{c}_{\mathsf{it}} + \beta_5 \mathsf{c}_{\mathsf{it}-1} + \beta_6 \mathsf{m}_{\mathsf{it}} + \beta_7 \mathsf{m}_{\mathsf{it}-1} \\ + \gamma(\mathsf{Y}_{\mathsf{it}-1} - \alpha_0 - \alpha_1 \mathsf{P}_{\mathsf{it}} - \alpha_2 \mathsf{C}_{\mathsf{it}} - \alpha_3 \mathsf{M}_{\mathsf{it}}) + \epsilon_{it} \end{aligned}$$

where again the term in the bracket is the error-correction term. A condition for the ARDL to be feasible is that all the series in levels are $I(1)$ or $I(0)$ but not $I(2)$. This condition is met below where all variables are indicated to be $I(1)$ (see Appendix 3.C).

Fixed effects estimation

For one short episode, the Great Depression (1929–1934), the time dimension has too few years to use a feedback system such as VAR or assume cointegration and use VECM. Instead, I use panel fixed-effects estimation, which is more suitable for cases with small T and relatively larger N. Given the relatively short duration of the Great Depression (relatively to the other samples), one lag is chosen. That is, a regression of output growth on its own lagged value and on the contemporaneous and lagged values of the other endogenous variables takes the form

$$\mathsf{y}_{\mathsf{it}} = \beta_0 + \beta_1 \mathsf{y}_{\mathsf{it}-1} + \beta_2 \mathsf{p}_{\mathsf{it}} + \beta_3 \mathsf{p}_{\mathsf{it}-1} + \beta_4 \mathsf{c}_{\mathsf{it}} + \beta_5 \mathsf{c}_{\mathsf{it}-1} + \beta_6 \mathsf{m}_{\mathsf{it}} + \beta_7 \mathsf{m}_{\mathsf{it}-1} + a_i + \epsilon_{it}$$

In estimations below, the exogenous regressors are added to the regression as well. The term a_i is the unobserved effect which contains all factors that may affect y_{it}, are country-specific and constant in time, but cannot be explicitly observed. I model a_i as a 'fixed effect', meaning that it is not an effect drawn randomly from a large population, but an effect that may be correlated with the regressors. The fixed-effects model is more suitable for the present case where the cross-sectional elements are countries, since these are not drawn randomly from a large population. In such a case, the fixed-effects model is more appropriate than the alternative random effects model which would require a_i to be uncorrelated with the regressors (see e.g. Wooldridge, 2002, p. 266).

The fixed effects a_i are represented by cross-section dummy variables in estimations below. However, as Nickell (1981) showed, estimated coefficients can suffer from inconsistency if the equation contains the lagged dependent variable $\mathsf{y}_{\mathsf{it}-1}$ among regressors. Although the bias falls at a rate 1/T as the number of years T grows, cases with small T risk inconsistent estimates. This is the case of the Great Depression (below in Section 3.4.4) which contains only 6 years. Hence, I also use the generalized method of moments (GMM) which uses instrumental variables from further past values of y that are not contained in the equation ($\mathsf{y}_{\mathsf{t}-2}$, $\mathsf{y}_{\mathsf{t}-3}$, etc.) and which provides consistent estimates. The GMM estimation I use follows Arellano and Bond's (1991) two-step procedure. A robust variance matrix estimator is used where heteroscedasticity or serial correlation are detected.[10]

[10] Estimation in this chapter was carried out using software packages E-Views and R.

3.4.2 Full Sample

Output, prices, consumption and money supply are all shown to be nonstationary in the full sample as the hypothesis of a unit root cannot be rejected at standard significance levels (see Appendix 3.C). Furthermore, Johansen cointegration tests (also Appendix 3.C) indicate that there are 2 cointegrating relationships between the four variables. As a result, the correct estimation model is VECM.

Table 3.8: VECM and Granger Causality: Full sample (c. 1870–2015)

	y_t		p_t		c_t		m_t	
	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.
EC term 1	0.000	0.512	0.002	0.806	0.001	0.135	0.003	0.706
EC term 2	−0.002*	0.094	−0.014	0.316	−0.001	0.102	−0.009	0.419
y_{t-1}	−0.025	0.390	0.830**	0.024	0.069**	0.025	0.795**	0.015
y_{t-2}	0.009	0.763	−0.859**	0.019	−0.001	0.983	−0.707**	0.029
p_{t-1}	−0.030**	0.023	−0.384**	0.021	−0.050***	< 0.001	−0.395***	0.008
p_{t-2}	−0.012	0.366	−1.765***	< 0.001	−0.043***	0.001	−1.540***	< 0.001
c_{t-1}	0.085***	0.002	−1.911***	< 0.001	−0.074**	0.010	−1.665***	< 0.001
c_{t-2}	−0.005	0.848	−1.249***	< 0.001	0.004	0.876	−1.065***	< 0.001
m_{t-1}	0.035**	0.018	0.444**	0.019	0.059***	< 0.001	0.462***	0.006
m_{t-2}	0.018	0.226	2.014***	0.004	0.055***	< 0.001	1.756***	0.000
Constant	0.008	0.662	0.041	0.860	0.016	0.411	0.144	0.479
$oilp_t$	0.014***	0.001	0.149***	0.003	0.013***	0.002	0.118***	0.009
$oilp_{t-1}$	−0.011***	0.005	0.166***	0.001	−0.006	0.152	0.150***	0.001
$oilp_{t-2}$	−0.005	0.255	0.032	0.534	−0.001	0.785	0.022	0.625
$Ypercap_t$	0.002	0.383	−0.003	0.914	0.005	0.813	−0.011	0.646
Observations	2154		2154		2154		2154	
Adj. R^2	0.017		0.084		0.024		0.081	

Null Hypothesis	p-value	Lags
p does not Granger cause y	0.045	2
y does not Granger cause p	0.004	2
p does not Granger cause c	0.000	2
c does not Granger cause p	0.000	2

Small-case variables are differences of natural logs of levels.
Coefficients estimated by ordinary least squares.
Cointegration assumes linear trend. Lag length in VECM is lag length determined by BIC for corresponding VAR in levels minus one, adjusted in case serial correlation was detected by the Ljung–Box Q test.
Price data exclude years where inflation is outside [-20%, 20%] annual change.

Figure 3.4: Impulse Response Functions: Full sample

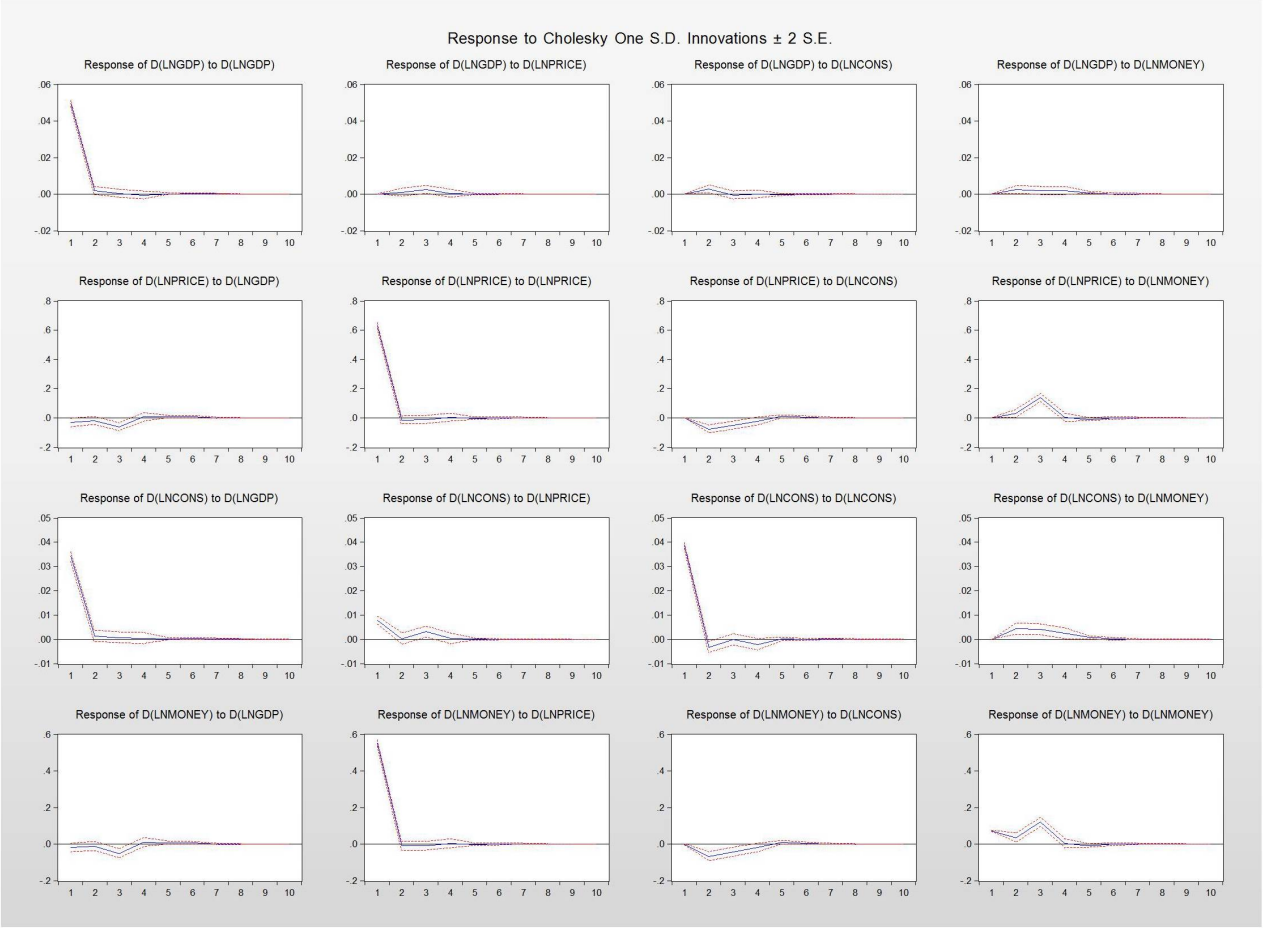


Table 3.8 presents results of a VECM with two lags, as determined by the Bayesian (Schwartz) Information Criterion.[11] There are two main results. First, the short-run coefficient estimates of an impact of inflation on output growth are slightly negative (-0.030 for p_{t-1} and -0.012 for p_{t-2}) and the first one is statistically significant. A similar result is seen with the effect of inflation on consumption growth, where both coefficients are slightly negative and significant. It should be noted that the economic magnitude of the effects is small: the coefficient estimate of -0.030 for p_{t-1} implies a reduction of 0.03 of a percentage point in growth rate of output if inflation increases by one percentage point. Second, there is little evidence of long-run convergence. The second error-correction term coefficient estimate for y_t is statistically borderline significant, but its magnitude of -0.002 implies a negligible rate of growth of adjustment. All other coefficient estimates for the error-correction terms are statistically insignificant.

[11]From now on, I use only the data that exclude observations of price change outside the interval [-20%, 20%] to make the results more applicable to the current price environment and more comparable to other studies that also use this practice. The exclusion of high inflation has caused the number of observations for Argentina, Brazil and Chile to drop steeply. As a result, they do not qualify for ARDL Pooled Mean Group estimates below. To make models and estimation methods comparable, I exclude these three countries from regressions from now on completely. They are only used for several selected charts and tables for the Great Depression and Japan below, which are not related to regressions. It is marked if they are used.

The responses to one-unit shocks to the system are plotted by cumulative impulse response functions in Figure 3.4.[12] Of most interest is second chart in the top row, which shows that a one standard deviation jump in inflation produces almost-zero (not even 0.01 times the shock) response in GDP growth. In the span of several years, the impact is zero. The impact of inflation on real consumption growth (third row, second column) is only slightly bigger in the short run, but still within the 0.01 range of the initial shock. The effect within several years is again zero.

For completeness, I also present in Table 3.8 Granger causality tests for relationships of most interest that follow from the estimated VECM. It is not surprising that in most cases, the hypothesis of no Granger causality is rejected, since the coefficient estimates are often statistically significant and Granger causality measures the combined significance of past values of one variable in predicting future values of another. Therefore, it can be said that inflation Granger causes output growth and that output growth Granger causes inflation, based on 2 estimated lags. However, the link from inflation to output growth is negative and very close to zero.

Most of the coefficient estimates of the other variables in the regression for y_t are broadly in line with expectations. Consumption lagged by one period has a positive and statistically significant effect on output growth, although the magnitude of the coefficient seems small. Lagged money supply growth has a small positive effect on output. Oil price growth as a supply-side factor is entered exogenously, so that contemporaneous as well as lagged effects are reported. The lagged effects of oil price growth on output growth are negative, which is in line with expectations. The contemporaneous coefficient is positive, which could rather mean that oil price growth peaks tend to happen when growth is peaking as well. The relatively small magnitude of the coefficients is not surprising since oil prices typically exhibit huge swings in percent terms. Therefore, a small coefficient estimate does not mean that oil price change does not affect growth. The level of economic development does not display a significant impact on growth in the whole sample.

On balance, the regressions for y_t and c_t show coefficient estimates in line with expectations. Some relatively large coefficient estimates with no apparent theoretical underpinning are in the other two regressions, such as the lagged negative effect of consumption growth on inflation and money supply growth. These remained even when changes to specification were made, such as adding lags to all variables. Some others, such as the positive impact of oil price growth on domestic inflation, are expected.

3.4.3 Comparison in Time: Monetary Regimes

In Section 3.3, it was shown that deflation was much more common under the classical gold standard before 1914 than in the period after World War I, when the gold standard was gradually loosened or abandoned and inflation became on average positive. The break in the monetary

[12] The impulse response functions from now on relate to the unrestricted VAR that corresponds to the reported VECM. The reasons for reproducing the impulse response functions for the VAR's are two. First, software packages normally do not produce panel VECM impulse response functions together with confidence intervals. Second, the main interest lies in the rates of changes of variables, not levels, for which purpose the response functions from the underlying VAR's are better suited.

regime could represent a change in the relationship between output growth and inflation. Unit root tests and Johansen cointegration tests (Appendix 3.C) indicate that both series are still non-stationary and cointegrated. As a result, VECM is used in both cases.[13]

Table 3.9: VECM and Granger Causality: Classical gold standard

	y_t		p_t		c_t		m_t	
	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.
EC term 1	0.000	0.706	0.001*	0.090	0.000	0.717	−0.002***	0.007
EC term 2	0.000	0.954	0.000	0.950	0.000	0.714	−0.005***	< 0.001
y_{t-1}	−0.164***	0.003	0.113*	0.054	0.145**	0.027	0.279***	< 0.001
p_{t-1}	−0.004	0.932	0.163***	< 0.001	0.051	0.311	0.065	0.267
c_{t-1}	−0.003	0.955	−0.086*	0.079	−0.324***	0.000	−0.113*	0.079
m_{t-1}	0.123***	< 0.001	0.242***	< 0.001	0.110***	0.006	0.200***	< 0.001
Constant	−0.032	0.310	−0.049	0.135	−0.006	0.877	0.170***	< 0.001
$oilp_t$	0.018***	0.006	0.014*	0.051	0.017**	0.026	0.019**	0.045
$oilp_{t-1}$	−0.012*	0.060	−0.003	0.702	−0.010	0.186	−0.020**	0.028
$Ypercap_t$	0.007*	0.072	0.005	0.209	0.003	0.481	−0.017***	0.002
Observations	481		481		481		481	
Adj. R^2	0.072		0.241		0.096		0.205	

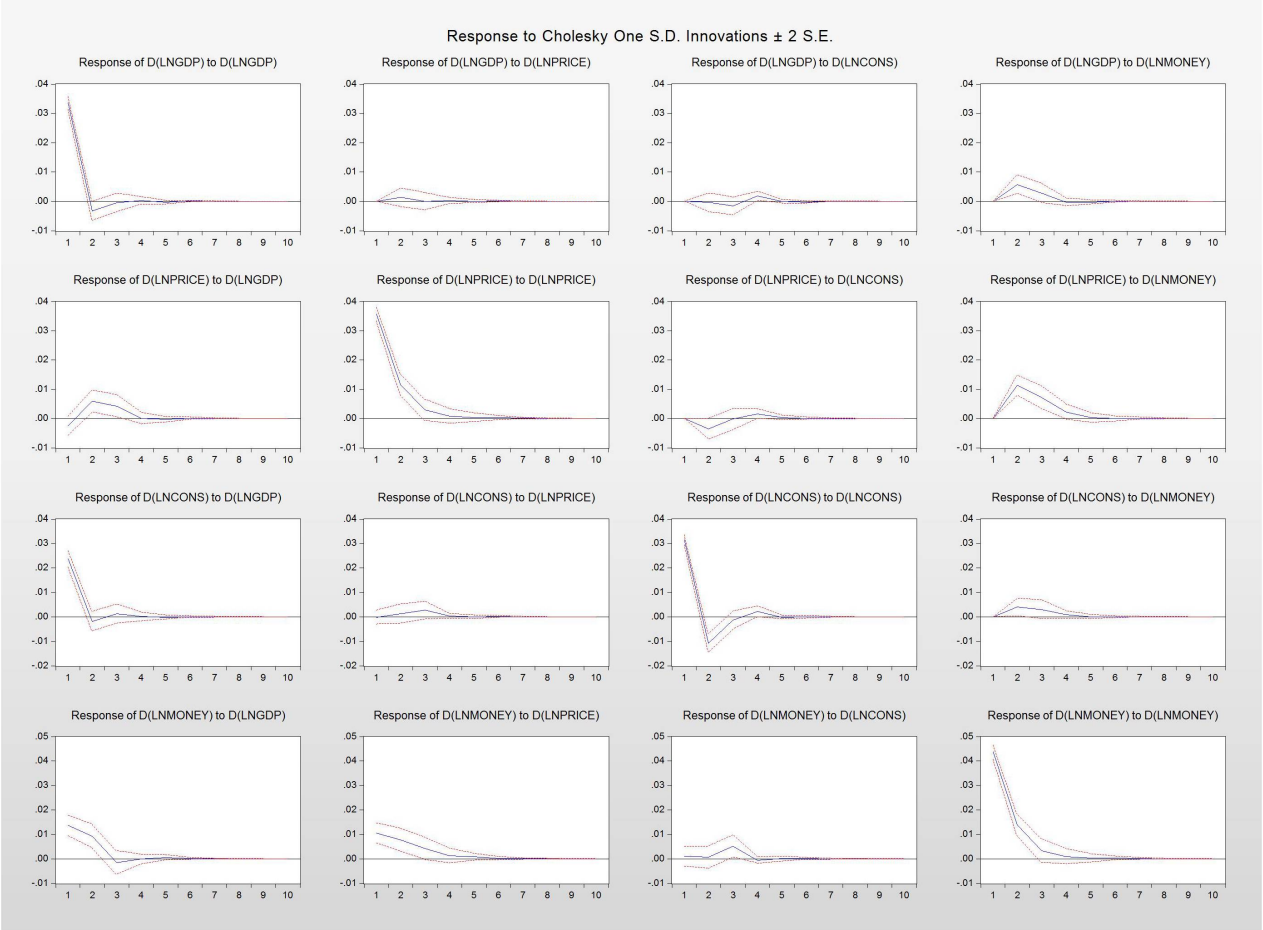
Null Hypothesis	p-value	Lags
p does not Granger cause y	0.932	1
y does not Granger cause p	0.054	1
p does not Granger cause c	0.312	1
c does not Granger cause p	0.079	1

Small-case variables are differences of natural logs of levels.
Coefficients estimated by ordinary least squares.
Cointegration assumes linear trend. Lag length in VECM is lag length determined by BIC for corresponding VAR in levels minus one, adjusted in case serial correlation was detected by the Ljung–Box Q test.
Price data exclude years where inflation is outside [-20%, 20%] annual change.

Tables 3.9 and 3.10 present regression results for each subsample. Again, the coefficients of the effect of price growth on output growth show either statistically insignificant estimates, or estimates that are slightly negative and statistically significant. Interestingly, this holds both for the effect on output growth and consumption growth, and applies to both monetary

[13]The split between the classical gold standard and post-classical gold standard was done country by country. It should be noted that the two subsamples do not exactly make up the full sample. The reason is that in some countries, there are observations even before the country could be considered to be on the gold standard. (Some countries joined only at the turn of the 19th and 20th century.) However, a vast majority of observations in the full sample belongs to either of the two subsamples.

Figure 3.5: Impulse Response Functions: Classical gold standard



regimes. The impulse response function for the effect of inflation innovations on output growth and consumption growth (Figures 3.5 and 3.6) are very similar to those reported for the full sample.

The relative stability of results when the full sample is split into two periods has interesting econometric as well as theoretical meanings. Estimating two parts of the sample separately does not bring a considerable change in the sign, magnitude and statistical significance of coefficient estimates, which underlines that the estimation of the full sample is relatively representative of its major parts when it comes to the effects of lagged inflation on growth. From the point of view of theory, although the two monetary regimes have important differences, e.g. in terms of the overall trend in money supply and prices and in the incidence of deflation, there does not seem to be a major difference in the lagged effect of inflation on growth.

3.4.4 Great Depression

Many theories on the consequences of deflation resulted from the experience of the Great Depression. Is this episode special?

Since the Great Depression episode is relatively short (from 1929 to 1934, i.e., 6 years in

Table 3.10: VECM and Granger Causality: After classical gold standard

	y_t		p_t		c_t		m_t	
	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.
EC term 1	0.000	0.271	0.001	0.528	0.000	0.954	0.001*	0.083
EC term 2	−0.001	0.655	−0.013**	0.013	−0.001	0.376	−0.009**	0.019
y_{t-1}	−0.004	0.923	0.429***	< 0.001	−0.046	0.188	0.367***	< 0.001
y_{t-2}	0.032	0.361	−0.069	0.534	0.018	0.602	0.026	0.767
p_{t-1}	−0.029*	0.090	−0.179***	0.001	−0.052***	0.002	−0.227***	< 0.001
p_{t-2}	−0.019	0.250	−0.145***	0.007	−0.031*	0.056	−0.101**	0.015
c_{t-1}	0.078**	0.036	−0.907***	< 0.001	0.084**	0.020	−0.707***	< 0.001
c_{t-2}	−0.032	0.365	−0.220**	0.044	−0.005	0.863	−0.153*	0.073
m_{t-1}	0.033*	0.088	0.218***	< 0.001	0.059***	0.002	0.276***	< 0.001
m_{t-2}	0.026	0.169	0.170***	0.005	0.041**	0.028	0.121**	0.011
Constant	0.041	0.114	0.331***	< 0.001	0.038	0.139	0.413***	< 0.001
$oilp_t$	0.019***	< 0.001	0.110***	< 0.001	0.013***	0.009	0.072***	< 0.001
$oilp_{t-1}$	−0.007	0.191	0.091***	< 0.001	−0.001	0.826	0.086***	< 0.001
$oilp_{t-2}$	−0.007	0.200	0.064***	< 0.001	−0.001	0.895	0.058***	< 0.001
$Ypercap_t$	−0.002	0.521	−0.032***	< 0.001	−0.002	0.516	−0.037***	< 0.001
Observations	1436		1436		1436		1436	
Adj. R^2	0.031		0.121		0.028		0.141	

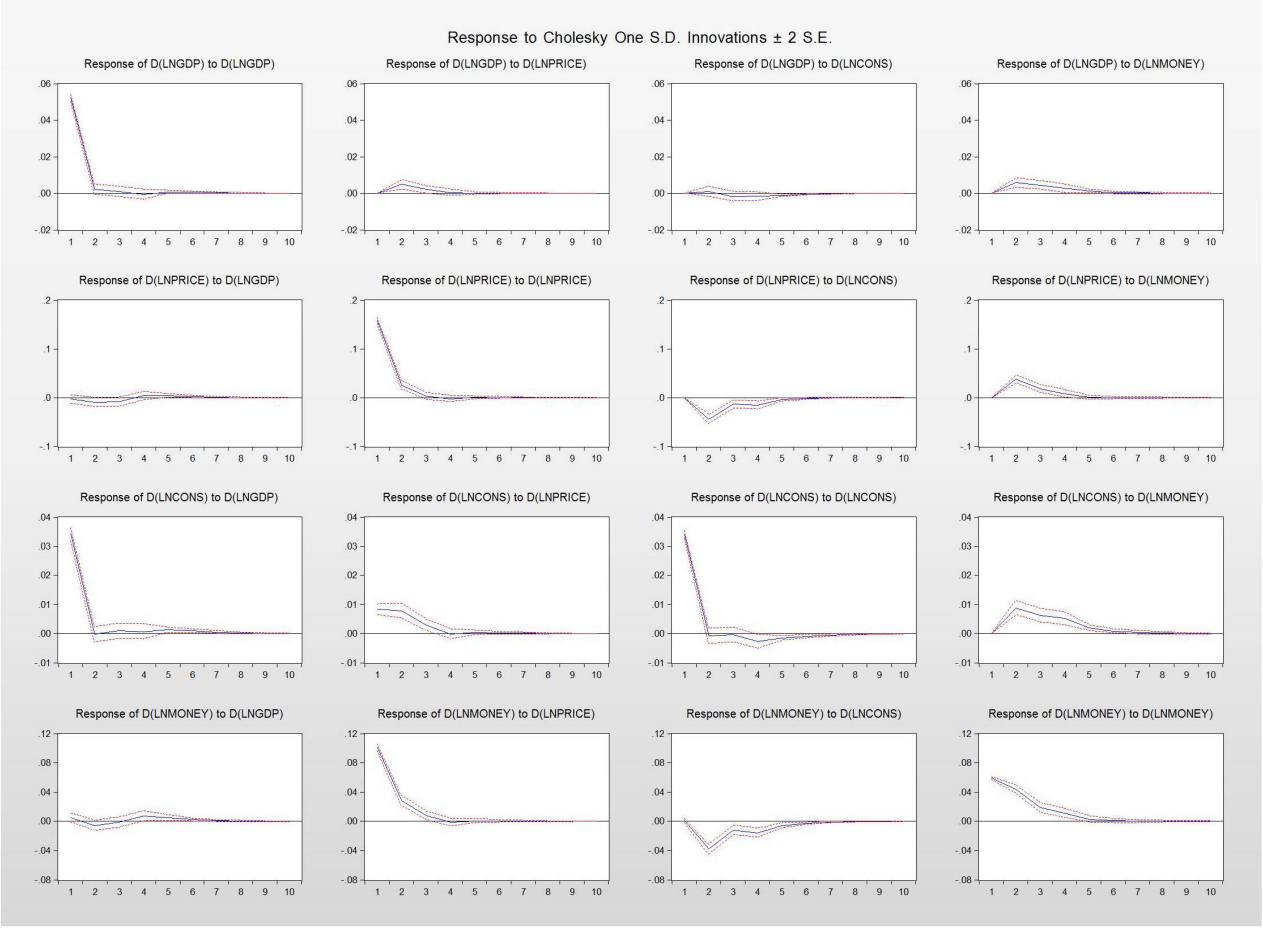
Null Hypothesis	p-value	Lags
p does not Granger cause y	0.109	2
y does not Granger cause p	< 0.001	2
p does not Granger cause c	0.001	2
c does not Granger cause p	< 0.001	2

Small-case variables are differences of natural logs of levels.
Coefficients estimated by ordinary least squares.
Cointegration assumes linear trend. Lag length in VECM is lag length determined by BIC for corresponding VAR in levels minus one, adjusted in case serial correlation was detected by the Ljung–Box Q test.
Price data exclude years where inflation is outside [-20%, 20%] annual change.

total), it is not suitable to use long-run feedback methods such as VAR and VECM. I use panel data methods instead with up to 1 lag of variables. Due to potential inconsistency in fixed effects estimation with the time dimension only $T = 6$ (see more in Section 3.4.1 on methods), I also include estimation of the same model by the generalized method of moments (GMM).

Table 3.11 presents the results of estimation for the Great Depression panel data set. I include three specifications: one with only price growth as independent regressor, the second one with money supply growth added and the third one with consumption growth and oil price

Figure 3.6: Impulse Response Functions: After classical gold standard



growth as further regressors. The reason for this is to check whether the inflation regressor takes on itself some of the effect of money supply growth and other regressors when these are omitted.

Indeed, there is evidence across all specifications of a relatively strong positive contemporaneous correlation between output growth and price growth. The coefficient estimates on p_t are 0.336 and 0.291 when all other regressors are included (last column), depending on the use of fixed effects or GMM. In both cases, the coefficient estimates are highly statistically significant. The economic magnitude is considerable: one percentage point increase in inflation would lead to roughly 0.3 percentage point increase in output growth, respectively. The fact that lagged coefficients of inflation are negative throughout (though not statistically significant) may not be surprising: the sample includes a period where economies first steeply fell from low inflation and growth (1929) to deep deflation and recession and then vice versa in 1934. Therefore, a deep recession in 1930 is associated with inflation or little deflation in 1929 and, similarly, recovery in 1934 is associated with deflation in 1933. This could produce the mentioned lagged estimates.

Specifications where some of the other regressors are left out show that inflation takes on itself considerably more effect. (This will be used below for comparison with studies that do not

include other regressors.) An effect like this is expected: a sharp drop in the money supply in the early 1930s throughout economies had a negative effect on growth and when money supply is left out of the regression, a part of its effect shifts to inflation. However, although money supply growth has the expected positive and statistically significant effect on output growth, there is still a sizable effect that stays with price inflation as such.

Table 3.11: Regression of output growth on inflation: Great Depression (1929–34)

	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.	$\widehat{\beta}$	p-val.
			Panel Fixed Effects			
constant	2.685***	0.001	1.544*	0.051	0.608	0.318
y_{t-1}	−0.035	0.770	−0.040	0.739	−0.213*	0.089
p_t	0.687***	< 0.001	0.530***	< 0.001	0.336***	0.004
p_{t-1}	−0.061	0.679	−0.158	0.302	−0.152	0.228
c_t	–	–	–	–	0.578***	< 0.001
c_{t-1}	–	–	–	–	0.138	0.325
m_t	–	–	0.383***	< 0.001	0.270***	0.005
m_{t-1}	–	–	−0.060	0.495	−0.018	0.836
$oilp_t$	–	–	–	–	0.047**	0.022
$oilp_{t-1}$	–	–	–	–	0.044*	0.063
Observations	102		102		102	
Adj. R^2	0.277		0.362		0.600	
			GMM			
y_{t-1}	0.237	0.176	0.071	0.420	−0.110*	0.055
p_t	0.530***	< 0.001	0.437***	< 0.001	0.291***	0.001
p_{t-1}	−0.253	0.128	−0.206	0.134	−0.182	0.110
c_t	–	–	–	–	0.534***	< 0.001
c_{t-1}	–	–	–	–	0.107**	0.030
m_t	–	–	0.333***	0.002	0.245***	0.006
m_{t-1}	–	–	−0.074	0.202	−0.005	0.919
$oilp_t$	–	–	–	–	0.058***	< 0.001
$oilp_{t-1}$	–	–	–	–	0.065***	0.001
Observations	85		85		85	
Adj. R^2	-		-		-	

Dependent variable: y_t.
All variables are in percent annual growth rates.
Price data exclude years where inflation is outside [-20%, 20%] annual change.
Fixed effects estimation: autocorrelation and heteroscedasticity robust standard errors used.
GMM uses y_{t-2} to y_{t-5} as instruments, two-step iteration, White robust standard errors.

It therefore appears that the Great Depression is fundamentally different from the rest of the sample, where there is no indication of a positive effect of inflation on output. (I provide

comparison across samples and with other research in Section 3.4.6.) This would suggest that there was indeed a further link between deflation and growth, on top of any effects caused by the money supply reduction.

Interestingly, there is not a consensus whether this effect was due to expectations and what the price link was. A leading candidate hypothesis to explain the unique link between deflation and depression experienced in the early 1930s is that this deflation was unanticipated. This hypothesis, if valid, would then trigger all the rigidity mechanisms described in Sections 2.3.1.2 to 2.3.1.4: potentially rigid nominal wages, nominally fixed debt contracts and nominal interest rates unable to drop below zero. However, from an empirical point of view, a consensus on whether the deflation during the Great Depression was anticipated or not has not been reached. Hamilton (1992) compared spot prices of commodities at the time with the prices of their futures contracts. Since futures prices were above the spot rates at the beginning of the Depression, Hamilton concluded that economic agents anticipated both commodity prices and consumer prices to at least remain stable. Hence, the actual deflation was according to him unanticipated. By contrast, Cecchetti (1992) found, based on three separate methods, that the early-1930s deflation is likely to have been anticipated. In this case, it is not debt-deflation or wage rigidity to blame, but rather high ex-ante interest rates that might have depressed investment and consumption. In other words, if economic agents were expecting sizable deflation, then real interest rates were ex ante higher than nominal interest rates at the time. This leads Cecchetti to infer that real interest rates were actually "very high from 1927 to early 1933" (Cecchetti, 1992, p. 142).

The Great Depression and Theory

The Great Depression serves as a prime example of how the price-output correlation may be explained by two completely different theoretical approaches.

The first approach sees deflation—in both the monetary and price meaning—as the cause of the depression. Friedman and Schwartz (1963a, 1963b) compiled data on US money supply and made the case that the key reason for the depression was the fall in money stock allowed by the Federal Reserve. It is essential that their reasoning was much more empirical than theoretical. Their data showed that a drop in money supply mainly affects prices in the long run, but affects prices *and* output in the short run. This played out fully in the early 1930s during a Fed policy that they found too restrictive and further worsened by a banking crisis. Friedman and Schwartz acknowledged, however, that the exact transmission mechanism of why this happens was unclear to them.[14] Despite this, Friedman's and Schwartz's account of the Great Depression laid the foundations for the currently prevailing view on the event. Many important works that followed built on their work. Eichengreen (1992) focused on the worldwide propagation of the Great Depression and argued that countries exported deflation and depression to one another

[14] Friedman and Schwartz (1963b, p. 55) state: "Of course, it is one thing to assert that monetary changes are the key to major movements in money income; it is quite a different thing to know in any detail what is the mechanism that links monetary change to economic change; how the influence of the one is transmitted to the other; what sectors of the economy will be affected first; what the time pattern of the impacts will be, and so on. We have great confidence in the first assertion. We have little confidence in our knowledge of the transmission mechanism, except in such broad and vague terms as to constitute little more than an impressionistic representation than an engineering blueprint."

through the international gold standard. Eichengreen considered the fall of money supply to be an amplifier and transmitter of the crisis, even if it might not have been necessarily the primary cause. However, the legacy of Friedman and Schwartz in his work is clearly visible. Bernanke (1995) followed up on Eichengreen and reaffirmed his opinion that the earlier a country left the gold standard and resumed monetary expansion, the earlier it resumed economic growth. Bernanke admitted that the depression was worsened by an insufficient drop in nominal wages, but he saw it as a secondary problem which would never have occurred had deflation been avoided.

While Friedman's and Schwartz's work was rather empirical, some studies building on them have shown more distinct theoretical background. Christina Romer (1992) shifted the focus more towards the Keynesian liquidity-trap theory and depressed investment. She found that monetary reflation was behind the sharp rebound in US economic output in the second half of the 1930s as it increased inflation and reduced real interest rates, helping to boost investment. Bernanke and Gertler (1989) and Bernanke (1995) elaborated on debt-deflation theories initiated by Fisher (1933): deflation impairs firms' net worth and impedes lending, which exacerbates the crisis. In sum, macroeconomists have tried to refine the arguments and bring new evidence, but the starting point of the analysis has mostly stayed the same since Friedman and Schwartz (1963a): monetary deflation triggering price deflation, which in turn activates various recessionary channels.

Relatively few authors have challenged the prevailing view. In his in-depth account of the Great Depression in the US, Rothbard (2000 [1963]) considered the previous money supply expansion in the 1920s to be the root cause of the depression and the depression itself as liquidation of malinvestment that had been allowed by loose monetary policy. In his opinion, one of the reasons why the depression was so severe was that the Fed had reacted to every sign of correction in the 1920s by providing still more monetary accommodation and still lower interest rates.[15] In addition, according to Rothbard the adjustment in the United States was obstructed and thus prolonged by the government's intrusion in the setting of prices and especially wages.[16] The key element of Rothbard's account is that price deflation was only a symptom of the adjustment process that was long overdue after a decade of money supply inflation, artificially low interest rates, stock market boom and allocation of credit to unsound projects. Therefore, in Salerno's (2003) terminology, the Great Depression saw mainly bank-credit and cash-building deflation as symptoms of the adjustment.[17]

The main difference of the two approaches is evident. While Rothbard interprets the Great

[15] Bagus (2015) arrives at a similar conclusion for the Great Depression in Germany: "There are several reasons why the depression was more severe than others, most significantly, the enormous credit expansion initiated in the U.S. and expanded further by German banks building credits on top of it."

[16] More recently, this view was supported by Ohanian (2009) who emphasized the role of labor unions and government in preventing nominal wages from adjusting downward, creating mass unemployment.

[17] Borio and Filardo (2004, p. 295), without going into more theoretical details, give a description that might fit this latter view of the Great Depression period: "(...) part of the weakness in economic activity observed during periods of deflation may not arise from deflation itself, but result from developments for which, at best, deflation acts as a symptom". Borio et al. (2015, p. 48) conclude that "it is misleading to draw inferences about the costs of deflation from the Great Depression, as if it was the archetypal example. The episode was an outlier in terms of output losses; in addition, the scale of those losses may have had less to do with the fall in the price level per se than with other factors including the sharp fall in asset prices and associated banking distress."

Depression as an inevitable consequence of processes that had been activated by monetary expansion in the 1920s, the Friedman-Schwartz tradition starts only in 1929–1930 and argues that if the Fed had made sure that the previous monetary trends continue, the Depression could have been avoided. This theoretical divide is deep, but both approaches are consistent with the empirical correlation between deflation and recession provided in this section. Output might have dropped due to deflation because of postponed consumption, depressed investment or debt-deflation, but it also could have dropped as a result of liquidation of bloated unprofitable projects and unreasonable government interference, with deflation only as a by-product.

Heterogeneity across Countries

Although the Great Depression overall shows a link between deflation and recession, the picture is not as unambiguous as is commonly believed when we extend the view in time and space. There are two interesting aspects of the data at hand: one regards what preceded the Great Depression and the other regards cross-country differences.

First, deflation in most countries did *not* appear simultaneously with the Great Depression. Figures 3.7 to 3.10 show that in many countries, prices started falling already in the 1920s when most economies grew solidly. This illustrates the pitfall of analyzing only the most debated period 1929–1934. Deflation in the 1920s could well have been of the 'good' sort, reflecting growth in output. But if inflation and deflation are defined in terms of prices and regarded purely statistically, then the malign price deflation of the 1930s should be weighed against the relatively benign price deflation of the 1920s.[18]

Second, countries differed sharply in terms of decreases in prices and output. Figure 3.7 shows the United States and Germany, which are the textbook cases of 'malign' deflation. Both countries went through a deep and long slump in output accompanied by a deep drop in prices. A similar situation was experienced by Canada, Argentina, Brazil, Chile, Australia and to a certain extent also France.

However, other countries had very different experiences. I show three different pairs of countries in Figures 3.8 to 3.10. Japan and Norway (Figure 3.8) did have sharp recessions, but these lasted only one year and their economies quickly recovered while prices kept falling. Norway is a striking case as it had been experiencing deflation many years before any recession came and also long after the recession ended. Italy and Denmark (Figure 3.9) had only moderate recessions that one would probably hesitate to call the 'Great Depression'. In Italy, real GDP was higher in 1934 compared to 1929 while prices continued to drop every year.

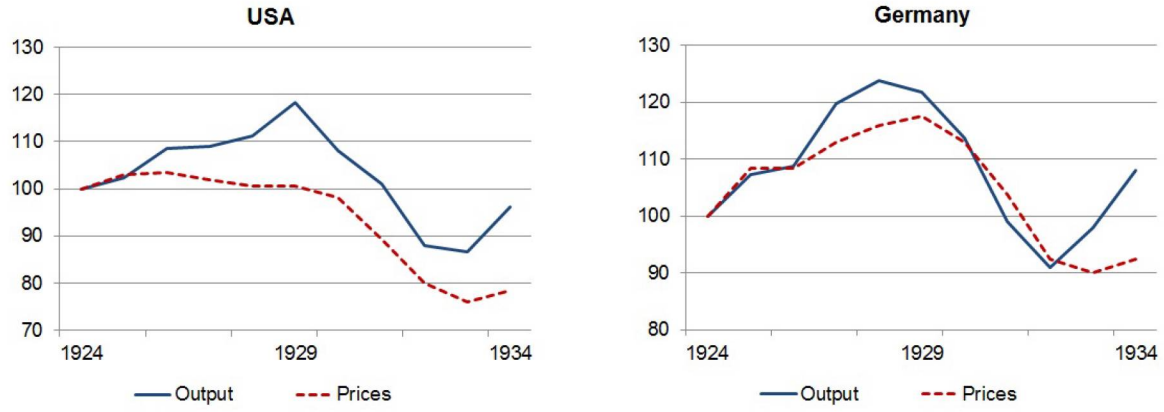
Finally, Figure 3.10 shows atypical evolutions of output and prices in the Netherlands and in Portugal. The Netherlands had an extreme drop in prices, unseen even in the United States. Its price level dropped 47% between 1924 and 1934. If we narrow our attention to the period 1929–33, prices in the Netherlands dropped by 28%, a quicker pace than in the US (24%). However,

[18] The fact that deflation appeared already in the 1920s in many countries opens the question whether deflation in 1929–1934 was anticipated or not. Atkeson and Kehoe (2004, p. 99) write: "To the extent that the deflation in the Great Depression is thought of as unanticipated as in most existing theories, this episode is not relevant for evaluating the costs of anticipated deflation." Figures 3.7 to 3.10 show that deflation was already present before 1929, but certainly in much smaller magnitude than after 1929. In Table 3.13 below I show the negligible deflation in modern Japan compared to that of the Great Depression.

output decreased only by 6%, while in the US output decreased by 27% over the same period. This starkly different situation with a similar drop in prices suggests that the rate of deflation alone cannot account for the depth of the depression. The second atypical case is Portugal, which defies the pattern seen in other countries. Portugal had repeated sharp recessions in the 1920s, but its economy started a rapid growth phase in 1931 while prices continued to fall.[19]

It is outside the scope of this text to analyze the situation in each country and find out why the evolution of output differed so much across countries. The point here is to highlight the empirical differences—i.e., that the Great Depression was not a homogeneous event from the perspective of prices and output. One thing can be said for sure: although the early 1930s recession appeared in almost all countries, deflationary years on the whole were not at all a synonym for recession. Nevertheless, it seems that the sharp concurrent drop in output and prices in the US affected American academic research which for long analyzed the Great Depression as the main deflation example.

Figure 3.7: Great Depression and before (1924 = 100): Deep and long contractions



[19]Few studies point out the heterogeneous character of the Great Depression across countries. One of the exceptions is King (1994) who points to the much deeper slump of GDP and consumption in the United States, Canada and Germany as opposed to other countries. He notes that the United States had a much quicker rise in household debt in the 1920s than the United Kingdom, which could explain the much shallower recession in the UK in the 1930s.

Figure 3.8: Great Depression and before (1924 = 100): One-year sharp contractions

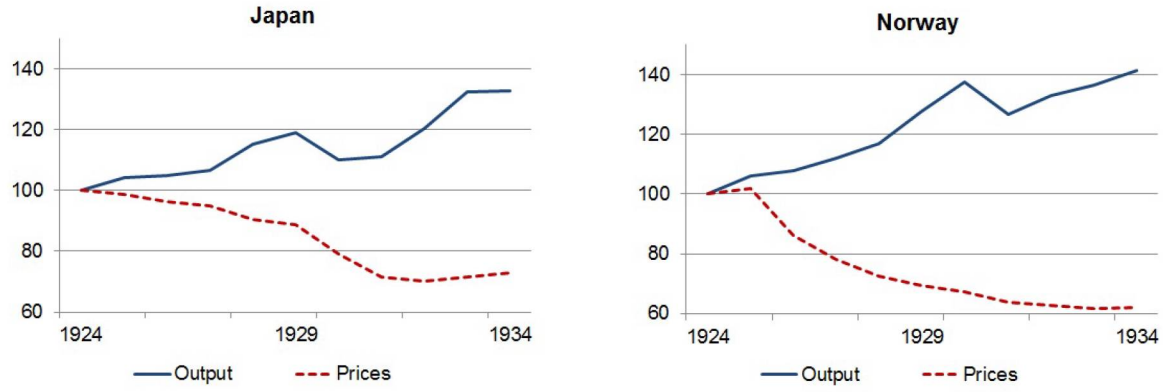


Figure 3.9: Great Depression and before (1924 = 100): Moderate contractions

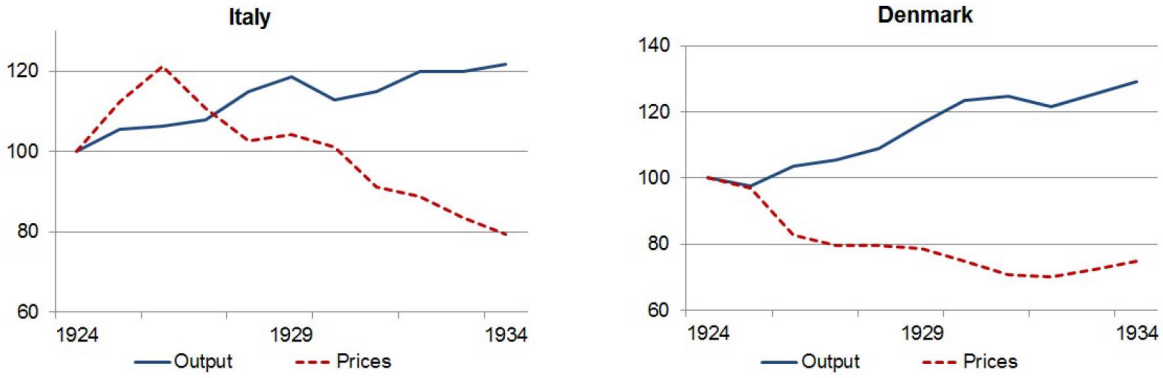
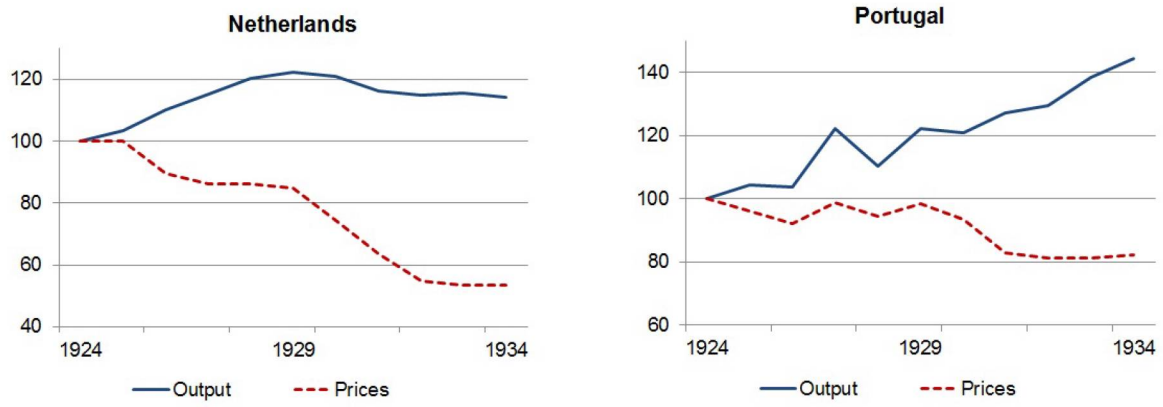


Figure 3.10: Great Depression and before (1924 = 100): Atypical cases



3.4.5 Contemporary Japan

Around 1992, Japan's economic growth slowed markedly and has not recovered ever since. In the period 1990–2015, Japan's economy grew on average by 1.15% per year and if we leave out the boom year 1990, the average growth rate drops to 0.99%. At the same time, inflation slowed down and in 1995, Japan recorded its first annual deflation since 1958. The relatively poor growth performance has been often directly linked to deflation. For example, Kuroda (2016) recently stated that Japan's economic difficulties are mostly linked to deflation. While deflation during the Great Depression was according to him an 'acute disease', in today's Japan it has become a 'chronic disease' (ibid, p. 2), but working through the same mechanisms as during the Great Depression. Kuroda echoed a widely cited article by Krugman (1998) who asserted that Japan is a modern textbook case of liquidity trap. Since nominal interest rates are at zero, standard monetary policy is inefficient in boosting aggregate demand and any deflation translates into a rise of the real interest rate, discouraging current consumption and investment. Bernanke (2003, p. 75) stated likewise that "Japan's negative inflation rate is too low for the country's economic health".

Given the amount of attention that Japanese deflation has received, it is warranted to give the Japanese experience a special place. I will first lay out regression results and basic observations that are important in thinking about Japan's deflation. Then I will discuss the key issue of whether Japan's growth issue has been evaluated accurately given its specific demographic development.

Inflation and Growth in Japan

The analysis of Japan covers the years 1990–2015. The fact that we are now dealing with only one country over 25 years requires the use of quarterly data. For Japan, I use all variables as in the samples above except real consumption, which is available on quarterly basis only beginning in 1995 and which I leave out. I use all data below in seasonally adjusted form. As shown in Appendix 3.C, unit root tests indicate that output and money supply are non-stationary series while prices are stationary. This is in line with the relatively flat development of prices over the period. The Johansen cointegration test does not reject the hypothesis of one cointegrating relationship. Therefore, I estimate a VECM where the number of quarterly lags is set at 8 to cover two years of potential delayed effects.

Table 3.12 presents the results. Given the high number of lags and coefficient estimates due to quarterly data, I only report the coefficient estimates for price growth in the regression for output growth.[20] The results seem to be relatively straightforward. Neither of the lagged coefficients of price growth on output growth has a statistically significant estimate. This is reflected in the non-rejection of the hypothesis that price growth does not Granger cause output growth. Also, the impulse response function on the effect of innovations on growth (top middle in Figure 3.11) indicates virtually no effects in the short or long run. Regarding the coefficient estimates of the error correction terms, there are none which would be both negative and statistically significant. Therefore, there is not evidence of long-run convergence.

Several observations on Japan's output and prices in 1990–2015 may clarify why the VECM

[20] Growth rates of all variables are now measured quarter-on-quarter.

Table 3.12: VECM and Granger Causality: Contemporary Japan (1Q1990–4Q2015): Lagged coefficients for inflation on growth

Lag of inflation	$\widehat{\beta}$	p-val.	Lag of inflation	$\widehat{\beta}$	p-val.
p_{t-1}	−0.131	0.672	p_{t-5}	−0.048	0.883
p_{t-2}	−0.093	0.766	p_{t-6}	0.131	0.678
p_{t-3}	−0.329	0.292	p_{t-7}	−0.449	0.205
p_{t-4}	−0.355	0.270	p_{t-8}	0.356	0.305

	y_t		p_t		m_t	
EC term	−0.056	0.356	0.067***	0.006	−0.031	0.211
Observations	95		95		95	
Adj. R^2	0.369		0.446		0.567	

Null Hypothesis	p-value	Lags
p does not Granger cause y	0.552	8
y does not Granger cause p	0.951	8

Dependent variable: y. Exogenous variable: oilp. Small-case variables are differences of natural logs of levels. Coefficients estimated by ordinary least squares. Cointegration assumes linear trend. Due to high number of lags (quarterly data) only coefficient estimates of p reported.

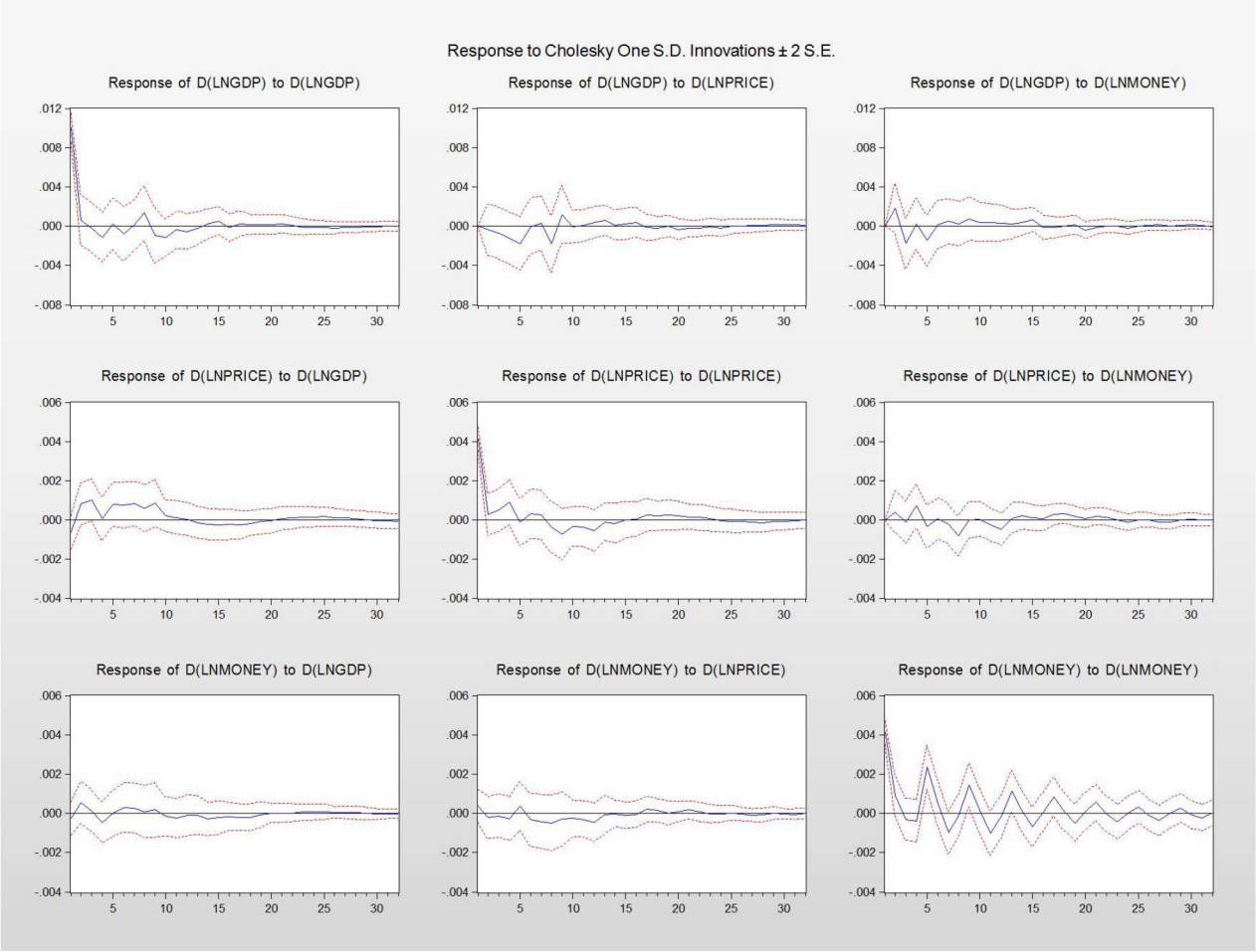
does not provide evidence of a deflation-recession link. First, most of Japan's deflation occurred not during recessions, but during the longest modern Japan's growth period in 2000–2007 (see Figure 3.12, part (a)). This observation does not support Kuroda's (2016) opinion that deflation was the driver of economic weakness. It also illustrates well the crux of the disagreement over Japan among economists. On the one hand, it is argued that lower inflation rates in the 1990s were associated with lower output growth as compared to previous decades. While this observation is correct, it is also true that since the 1990s, deflationary years have been accompanied almost exclusively by growth, not recession (Figure 3.12). The comparison of the price level and the unemployment rate in part (b) of Figure 3.12 also illustrates the situation. In 1990–2015, the unemployment rate dropped more often after a decrease in prices rather than after an increase in prices.[21] [22]

Second, since 1992 (when growth decelerated sharply) prices in Japan have shown either very mild inflation or very mild deflation, with the inflation rate always in the (-2%, 2%) interval except for one year. Overall, the price level grew a cumulative 9.6% between 1990

[21] Data on unemployment are from the OECD (2016).

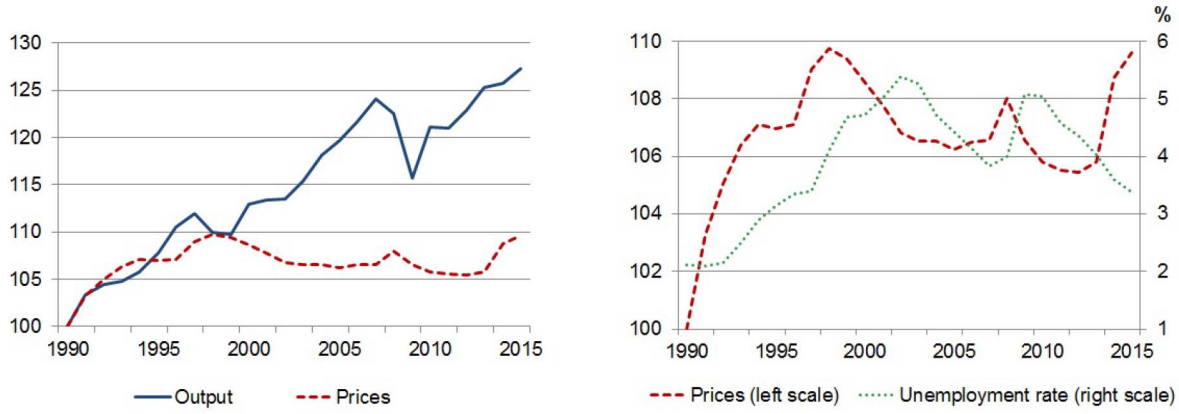
[22] There is little consensus in the literature over the sources and character of Japan's mild deflation. Johnson (2005) analyzes money supply, prices and aggregate demand in Japan in the 1990s and finds that there were more years of growth deflation than years with deflation resulting from falling aggregate demand. This is in line with the present finding. In contrast, Cargill and Parker (2004b) find that deflation in Japan was demand-led and highlight its adverse effects.

Figure 3.11: Impulse Response Functions: Contemporary Japan (1991–2015)



and 2015 (see Figure 3.12). As such, Japan's mild deflation episodes are incomparable with the deep deflation during the Great Depression or with the frequent and sizable deflation during the classical gold standard. Table 3.13 provides several price and output statistics on current Japan, Japan during the Great Depression and the United States during the Great Depression. The main message of the table is that even in the early 1930s, Japan did not mirror the American experience with deflation and depression, and still much less from the 1990s until now. For one thing, the deflationary episodes in modern Japan are negligible in size compared to the depths of deflation during the Great Depression. But more importantly, Japan does not share the same bad experience with deflation and recession as the United States. The deepest cumulative drop in prices (i.e., over consecutive years of deflation) in modern Japan occurred in 1998–2005 when prices dropped 3.2% from peak to trough and at the same time output *increased* 8.8% (see Table 3.13). By the Bank of Japan's (2017) definition of deflation as 'sustained decline in prices', this period qualifies as the only deflationary period in modern Japan and yet it contained the longest boom phase. This is sharply different from the Great Depression in the US where prices dropped 24.4% over 1930–33 and output collapsed by 26.7%. Therefore, there

Figure 3.12: Contemporary Japan (1990 = 100): (a) Output and prices, (b) Unemployment rate and prices



should be caution in applying the experience of the Great Depression to modern Japan.[23] As shown in Section 3.4.4, the Great Depression indeed saw a statistical link between deflation and recession, but the pace of price decreases was much quicker and the correlation seems to be an exception from all other historical experience. Theories that presuppose a strong negative impact of deflation on growth based on the Great Depression may be unsuitable for modern Japan.[24]

Third, the mild deflation that has repeatedly occurred in Japan is asking for particular theoretical questions. Given that the Japanese encountered deflation mostly between -1% and 0% (only the crisis year 2009 had deflation deeper than -1%), could this have tangible economic consequences? Suppose, based on this observation, that the annual rate of deflation is -0.5%. For example, if we applied the assumption that deflation induces people to postpone consumption and that this slow rate of deflation could induce deflation expectations, it is difficult to conclude that consumers would wait one year with their purchase in order to save 0.5% of the price. In other words, personal discount rates would have to be virtually zero in order to make this mechanism work. By the same token, if the Japanese economy was in a liquidity trap, deflation would only cause a 0.5 percentage point difference between nominal and real interest rates. Indeed, Figure 3.13 shows that after the dramatic drop in the early 1990s, both nominal and real interest rates have spent the last 20 years essentially around zero.[25] It seems unlikely

[23] For instance, Burdekin and Siklos, (2004, p. 18) write that "The Japanese experience seems, in fact, to have many parallels with that of the United States around the time of the Wall Street Crash of 1929." While the run-up to the crisis might have been similar, the ensuing evolution of prices and output is starkly different.

[24] Borio and Filardo (2004) is one of the few studies that doubt a major effect of deflation on output in Japan, stating that "it is hard to see how the mild deflation experienced there over the last few years could be the *primary* reason for output stagnation" (p. 295, emphasis original).

[25] These are ex-post interest rates. Ichiue and Nishiguchi (2014) show that over 2006–2013, inflation expectations of consumers were markedly positive. Hori & Shimizutani (2005) find that inflation expectations ranged from -0.2% to 0% in 2001 - 2002 and grew above zero afterwards, which is in line with Ichiue and Nishiguchi.

Table 3.13: Contemporary Japan and Great Depression: Comparison

	Japan 1990–2015	Japan 1929–1934	US 1929–1934
Cumulative price change	+9.6%	-17.9%	-22.0%
– Corresponding output change	+27.2%	+11.5%	-18.7%
Average annual price growth	+0.4%	-4.8%	-6.0%
– Corresponding output growth	+1.0%	+2.8%	-5.1%
Years of longest consecutive deflation	1999–2005	1929–1932	1930–1933
– Corresponding cumulative price change	-3.2%	-20.9%	-24.4%
– Corresponding cumulative output change	+8.8%	+1.3%	-26.7%

Annual growth denotes compound annual growth rate (geometric mean).

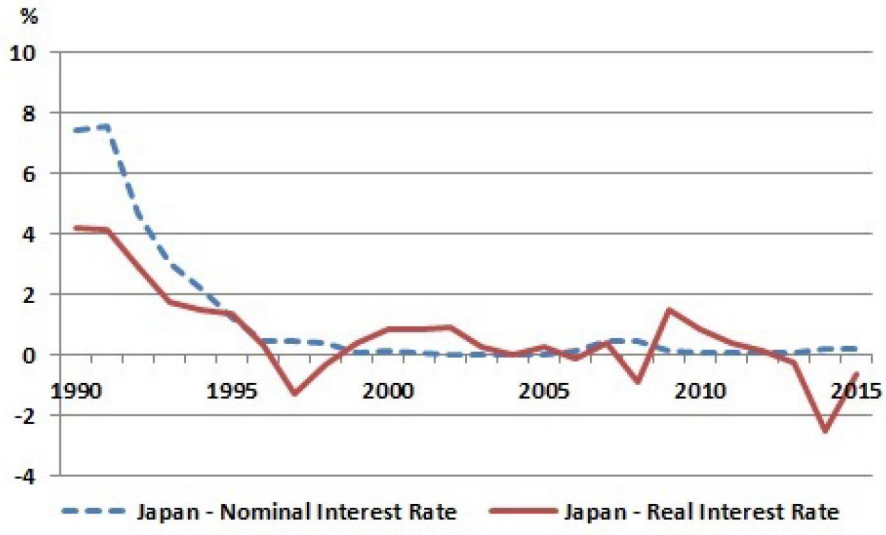
that zero real ex-post rates and negative ex-ante rate have still been so high to become the primary or even the only reason for Japan's slow growth.

Finally, the debt-deflation theory rests on the assumption that debtors are caught by surprise by a sudden appearance of deflation when they cannot change their nominally specified contracts. But it seems unlikely that contracts in Japan would not be adjusted to this possibility after, say, 10 years of recurring episodic deflation. While this mechanism could have theoretically played a role in the mid-1990s when mild deflation was a novelty, it is improbable that it has had an effect in the past decade. Baba et al. (2005, p. 4) show that the ratio of interest payments to cash flow actually fell sharply for Japanese companies throughout the 1990s, which suggests that debt-deflation mechanisms were probably not at play.

All in all, if anything could be deduced from the behaviour of output and prices in Japan in 1990–2015, it is that there was no clear association of inflation and growth and that deflation was so mild that it alone was unlikely the culprit of slow growth. While the theories which assert that deflation is harmful could be applicable to the depth of deflation seen in the Great Depression period, they seem difficult to apply to the modern Japanese experience. This is also supported by the full sample for all countries and all years: observations with inflation rate in the interval (-2%, 2%)—which Japan had all the time between 1992 and 2015 except for one year—have an average output growth of 2.8% per year in the entire data set. This suggests that the rate of inflation common in Japan is in no way generally associated with subpar growth. Either the reasons for slow growth are more likely to lie elsewhere or the 'slow growth' hypothesis itself is not entirely valid.

Together, this implies that ex-ante real interest rates were negative most of the time for which we have data on inflation expectations.

Figure 3.13: Contemporary Japan: Nominal and real interest rates



Japan's Underperformance: Demography at the Forefront

There are two ways in which we can evaluate Japan's output underperformance. First, we can compare its growth rate since the 1990s with other advanced economies in the same period. Second, we can compare it in time with its own rate of growth prior to the 1990s. What mattered dramatically for Japan from the 1990s forward was the slowdown in demographic growth and ultimately its transition into demographic decline. The important age cohort for production which is statistically reported is the population between 15 and 64 years of age. Growth of population in this age cohort was around or slightly less than 1% per year in the 1980s, but started to slow down sharply around 1990, turned negative in 1996 and has continued in this trend ever since. Between 1990 and 2015, Japan lost 8.85 million people of age 15–64, which represents a 9% drop from 86.15 million people in this age group in 1990 to 77.3 million in 2015.[26] This naturally constitutes a drag on total production since the number of people able to work diminishes. From the point of view of production, this drop was partly offset by people over 64 years of age staying longer in jobs. However, this compensation has obvious limits both in terms of numbers and in the type of jobs older people can perform.[27]

To capture the effect of demographic development on growth, in Table 3.14 and in Figure 3.14 I show the growth rate of total GDP, GDP per capita, GDP per member of labour force and GDP per employed worker for Japan, the United States, the average of Germany, France and Italy and also the average of 18 'advanced countries', where I include all countries from my

[26]The source of demographic data in this section is World Bank (2017).

[27]A second factor related to labour force, which is almost absent from the literature, was the 1988 legislative shortening of weekly working hours in Japan. Average hours worked per week dropped from 44 hours to 40 hours, or 9%, between 1988 and 1993 (Hayashi and Prescott, 2002, p. 207), which reduced the labour input in production further.

macroeconomic data set except Argentina and Brazil.[28] I include GDP per member of labour force as a check because GDP per employed worker can be substantially affected by changes in unemployment in booms and recessions.

Table 3.14 and Figure 3.14 reveal strikingly different optics through which one can assess Japan. In terms of total GDP growth, Japan indeed fared significantly worse than the US or the average of advanced countries, although its growth rate is quite comparable to that of Germany, France and Italy on average. However, taking into account demography, the picture changes dramatically. Judging by GDP per capita, the growth rates of all the countries drop considerably except for Japan, which had only a slight increase in its total population. Especially the growth rate of the US does not stand out any more because its total GDP was boosted by swift demographic growth. Finally, the difference between Japan and the rest shrinks even further when looking at GDP per member of labour force and GDP per worker. Japan even had a quicker pace of growth of GDP per worker than the average of Germany, France and Italy. The bottom part of Table 3.14 shows the Welch t-test of the equality of average growth rates. There is a statistical difference only between Japan's rate and that of the United States and then Japan's rate and that of the advanced countries, when judging by total GDP growth. In terms of the per-head measures, the averages are statistically too close to reject their equality.[29] [30]

The inclusion of the average of Germany, France and Italy is not random. These economies are known to have slowed markedly in the 1990s just as Japan did. While Germany partly resumed growth around 2005, France has visibly lagged behind and Italy has not achieved any growth in real GDP since 2000. It therefore makes sense to compare the inflation record of these countries with that of Japan. Remarkably, while these three countries recorded similarly slow economic growth as Japan, their inflation rate was over 2% in 1991–2015, similar to the US and to the average of advanced countries, but much higher than Japan's 0.37% (see Table 3.14 and

[28] In comparing Japan's growth rate to other countries, it seems reasonable to only include advanced economies whose growth rate can be taken as a benchmark of feasibility for Japan. For this purpose, I took only OECD members, thereby leaving out Argentina and Brazil from the complete sample of 20 countries.

[29] Krugman (1998) acknowledged that Japan's growth must slow down due to the aging population. However, he did not compare Japan's output performance with other countries after taking into account demography and he did not view it as the main culprit of Japan's slowdown.

[30] Demography is not only key in judging Japan's economic growth, but it could also explain why deflation appeared in Japan in the first place. The aging population means that the most populous age cohort is shifting from young and younger-middle age towards older-middle age. While younger people tend to consume most of their income, people in the age cohort 40–60 tend to save a relatively higher portion of their income in order to build enough savings for retirement. As a result, population at this aging stage could dampen consumer prices. If this hypothesis is true (but its verification is outside the scope of this thesis), then demographics could be the reason both for Japan's growth slowdown and its inflation slowdown, but without the latter causing the former. Apart from aging population, other reasons for the marked inflation slowdown could be increasing trade with China (and hence imported deflation) and also a protracted correction from the late 1980s asset price bubble. The long correction of asset prices, house prices and land prices could shrink the value of loan collateral and credit available to consumers, thereby limiting growth in consumer spending and consumer prices. In this respect, it is worth noting that Japan's stock index Nikkei 225 was in a downtrend for almost 20 years (from the all-time high in October 1989 to the low in January 2009), which is unparalleled in any other major advanced economy. This is a testimony to how huge the asset price bubble was in the late 1980s and how long the correction took. Borio and Filardo (2004) and Borio et al. (2015) highlight the effect on output of asset price declines as opposed to consumer price declines.

Figure 3.14). This casts further doubt on the association of Japan's growth with deflation. The three biggest European continental economies grew at a similar pace, but with considerably higher inflation which matched the 2% target of most central banks. It appears that quicker inflation did not help Germany, France and Italy to post higher growth than Japan.

The second interpretation of Japan's alleged underperformance may be that since the 1990s, it slowed down compared to its own past growth rates. Figure 3.15 illustrates that this is indeed the case, but that the slowdown had begun already in the 1970s and then continued. The only interruption of the slowdown came in the late 1980s with the famous stock market and land prices bubble which temporarily boosted GDP growth. Apart from that, the slowdown resumed in the 1990s and it was further reinforced by the demographic break. Moreover, as Figure 3.15 shows, this slowdown was very similar to that experienced in Western Europe, as captured by the evolution of the average growth rate of Germany, France and Italy. Here the comparison between Japan and the trio of European countries has the additional appeal in that all of these countries had severe damage from World War II (especially Germany and Japan) and therefore were likely to have similar post-war growth dynamics including the eventual slowdown, which Figure 3.15 confirms.[31]

Figure 3.14: Contemporary Japan: Annual average growth by different measures (1991–2015)

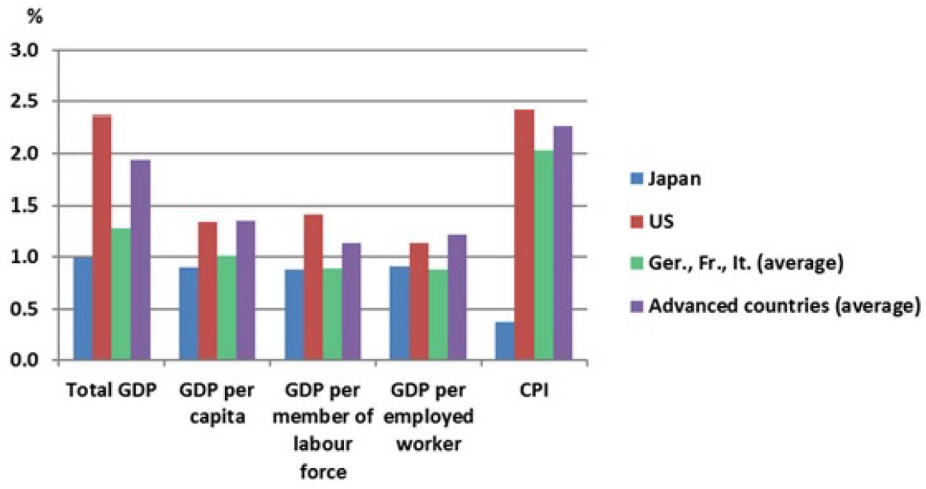


Figure 3.16 shows inflation rates over the same period. Consumer price inflation, too, had begun a slowdown long before the 1990s both in Japan and in Western Europe, and Japan's inflation had been significantly lower than that of Germany, France and Italy already in the 1980s. This is important because the two regions—Japan and Western Europe—were

[31] Atkeson and Kehoe (2004) point out that the initial burst of growth in the reconstruction phase in Japan after the war and the subsequent slowdown are consistent with the basic Solow model of convergence to steady-state rate of growth. Initially, growth of output is boosted by the replenishment of capital destroyed during the war. As capital is built up again, growth depends more and more on productivity growth (absent demographic growth). Needless to say, there could have been many more reasons for the slowdown, including the misdirection of investment in the 1980s asset price bubble, a rigid structure of the corporate sector in Japan (keiretsu), the culture of government bailouts of unprofitable companies, and others.

Table 3.14: Measures of output growth in respective countries: average growth rate 1991–2015

	Japan	US	Ger., Fr., It. (average)	Advanced countries (average)
Average growth rate of:				
Total GDP	0.99	2.37	1.28	1.94
GDP per capita	0.89	1.34	1.01	1.36
GDP per member of labour force	0.87	1.42	0.88	1.13
GDP per employed worker	0.90	1.13	0.87	1.21
CPI	0.37	2.42	2.03	2.27
Average level of:				
Investment-output ratio	0.24	0.21	0.19	0.22

Tests of equality of means: p-values

	Japan's rate against that of:		
	US	Ger., Fr., It. (average)	Advanced countries (average)
Average growth rate of:			
Total GDP	0.009***	0.513	0.024**
GDP per capita	0.361	0.791	0.245
GDP per member of labour force	0.233	0.967	0.488
GDP per employed worker	0.153	0.947	0.357

Test used is the Welch unpaired t-test.

undergoing a very similar slowdown in GDP growth and at the same time, Japan had incessantly a much lower inflation rate.

Overall, the comparison of Japan and Western Europe in the 1990s and before gives a necessary relative perspective on Japan's performance. The bottom line is that Japan did not perform any worse than the average of Germany, France and Italy on per-worker basis and only slightly worse on total GDP basis, while it had consistently lower inflation. Therefore, it does not seem to be a satisfactory approach to explain Japan's growth issues by focusing only on its inflation rate.

Figure 3.15: Contemporary Japan vs. Germany, France and Italy: GDP growth

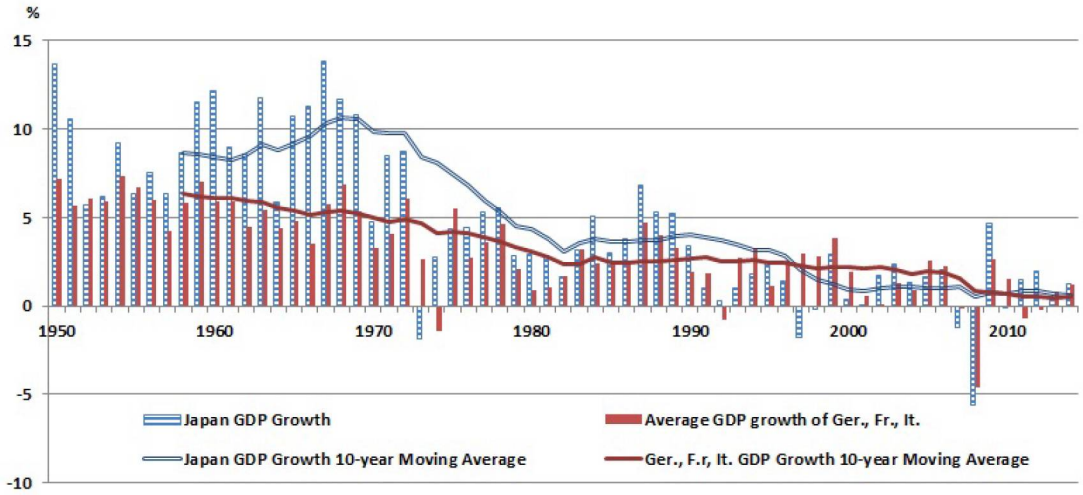
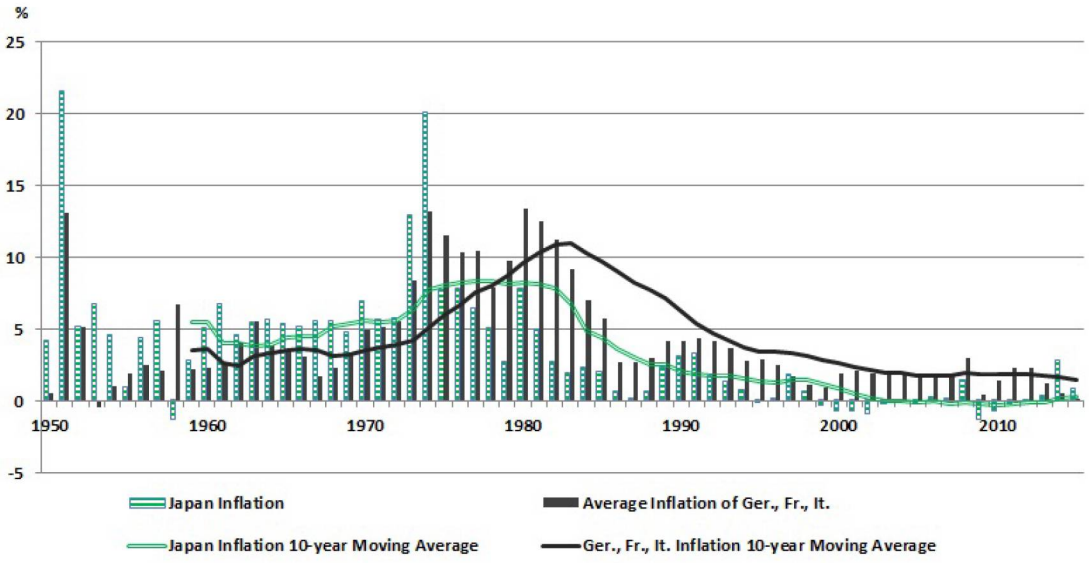


Figure 3.16: Contemporary Japan vs. Germany, France and Italy: Inflation



Amount of Capital or Return on Capital?

Krugman's (1998) interpretation of Japan's situation drew a direct comparison between modern Japan and the Great Depression. Krugman used Hicks's liquidity trap theory to assert that investment was hindered by firms' expectation of falling revenues together with high real interest rates, both due to deflation. In such an environment, firms have hardly any motivation to invest.

Krugman's (1998) and Kuroda's (2016) reasoning about depressed investment due to defla-

tion rests in the assumption that there are profitable projects to invest in, but the real interest rate is too high for firms to undertake them. For example, Krugman (1998, p. 161) writes in relation to Japan that "the economy needs inflation, because it needs a negative real interest rate". As shown in Figure 3.13, the real interest rate in Japan has been mostly close to zero and often negative. This is the result of nominal interest rates being permanently at zero and inflation being slightly positive on average. Therefore, if a project could not be undertaken, it is not because the real interest rate was too high relative to the project's internal rate of return.[32] All projects with a positive internal rate of return could be financed with such low rates as in Japan.

Hayashi and Prescott (2002) came up with an alternative explanation of Japan's difficulties. Although there was a credit crunch and banks restrained lending in the 1990s, firms managed to make up for the funds by selling land and assets which had reached high prices in the 1980s. As a result, corporate investment did not collapse. The problem, according to the authors, lay elsewhere. Investment faced lower rates of return as productivity growth sharply decelerated. In the language of a textbook production function $Y = A \cdot F(K, L)$, the problem was not slow growth in capital K as Krugman's reasoning would imply, but a slowdown in the growth rate of productivity A. According to Hayashi and Prescott (2002, p. 209), the growth of total factor productivity slowed down from 2.4% in the 1980s to just 0.2% in the 1990s, which explains the slowdown in the growth rate of output Y.

Hayashi's and Prescott's thesis is in line with the finding in this section. If there was too little investment in Japan—for example, due to the liquidity trap situation—Japan would lag far behind peers also in the per-worker statistics because given the dwindling labour force it would have hardly any source from which to generate growth. The fact that Japan still managed to increase its per-worker output at approximately 0.9% per year in a situation with almost zero growth in total factor productivity indicates that it was precisely the considerable amount of investment that kept the economy growing. To use the notation of production function $Y = A \cdot F(K, L)$, while labour L was hindered by unfavourable demography and total factor productivity A slowed down sharply, it was only capital K that could 'save' Japan's growth.

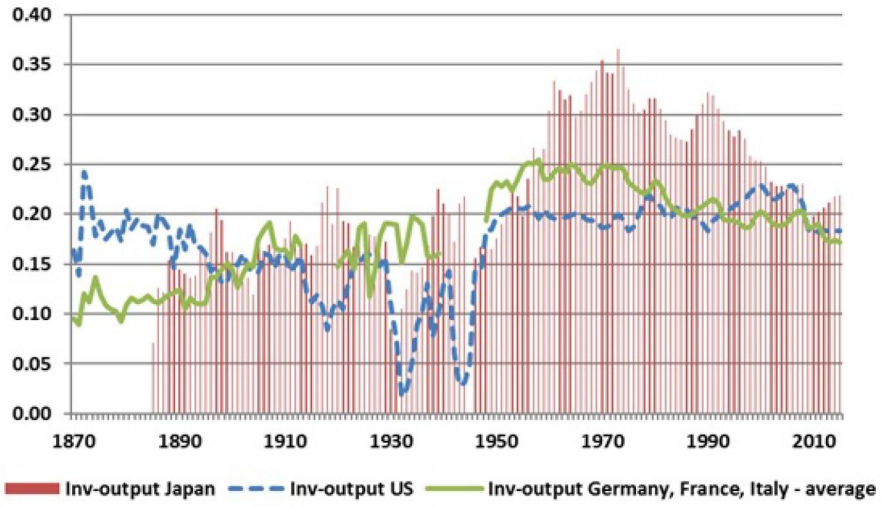
This interpretation is supported by the investment-output ratio. Japan's fraction of investment on output was 0.24 on average over 1991–2015, which is more than the US, the average of Germany, France and Italy and the average of advanced countries (Table 3.14). Although the investment-output ratio fell throughout the 1990s and afterwards, Figure 3.17 illustrates that it did so from very high levels that were atypical both for Japan historically and for the the US and Western Europe anytime in their history. In other words, Japan only rejoined in the 1990s and 2000s the levels that were normal for its counterparts. The slide from records had already started in the 1970s, but was interrupted by the late 1980s boom, similarly to real GDP growth.[33]

This analysis casts some doubt on two deflation-recession theories in case of Japan. It does not seem likely that growth was hampered by too high real interest rates due to deflation (Krugman, 1998) or by the breakdown of financial intermediation due to deflated collateral

[32] The internal rate of return is such a rate that makes the net present value of a project equal to zero. The higher is the rate, the more profitable is the project.

[33] This development of the investment-output ratio is again consistent with the hypothesis of catching-up of the capital stock for several decades after World War II, but eventually slowing down.

Figure 3.17: Japan, US, and avrg. of Germany, France, Italy: Investment-output ratio



(Bernanke and Gertler, 1989) because evidence suggests that firms did not lack capital for investment. Instead, it seems more interesting to ask what might have gone wrong with the structure and productivity of the Japanese economy. Importantly, Hayashi's and Prescott's analysis is in line with the finding of this section that Japan's low inflation and occasional deflation is very unlikely to be linked to subpar growth.

3.4.6 Comparison and Discussion within ARDL and Fixed Effects Models

One practical disadvantage of the VAR/VECM estimates is that we do not have coefficient estimates of contemporaneous effects of inflation on growth. In contrast, the Great Depression period, which is relatively short compared to the other samples, was estimated using more short-run, panel methods, where I obtained contemporaneous and one-year lagged effects. In order to be able to compare panel samples of different length, I estimate each of them in Tables 3.15 and 3.16 using two methods: the Pooled Mean Group estimator as a method for autoregressive distributed lag (ARDL) models, and fixed effects as a panel method.

The rationale for estimating a single-equation ARDL model with an error-correction term and with y_t as the independent variable comes from the VECM estimates above. Because the coefficient estimates of the error-correction term for the other regressions (p_t, c_t, m_t) were mostly statistically insignificant or, if significant, very close to zero, then the variables p_t, c_t, m_t could be understood as weakly exogenous for y_t, so that the effects on y_t may be estimated in a single equation with the three other variables as regressors. However, since the Johansen cointegration tests (Appendix 3.C) indicate the presence of two cointegrating relationships in the three major samples (full sample, classical gold standard and after classical gold standard), the single error-correction term in the ARDL model represents a linear combination of these two cointegrating relationships. This deprives the coefficient estimates attached to it of a structural

meaning. Therefore, the focus of ARDL estimates in Tables 3.15 and 3.16 is on short-run influences, not on the error-correction term. This is why it is complemented by fixed effects estimation, which also focuses on rather short-run effects. The Pooled Mean Group estimator and the fixed effects model in this section could provide a useful 'competitor' model to the VECM's estimated by OLS above, so that the results could be better supported.

Tables 3.15 and 3.16 include various samples. First, there are the main samples analyzed above by the VAR/VECM framework (full sample, classical gold standard and after classical gold standard). Second, I have reduced the full sample and the 'after classical gold standard' to subsamples that contain only observations of deflation. This serves to see whether the link between price growth and GDP growth is not considerably different when we restrict inflation only to negative values, as opposed to any values between [-20%, +20%] which apply to the full sample. Third, there is the short Great Depression sample and also the sample of all data except the Great Depression ('Full ex Great Depression'). Since the Great Depression lasted only 6 years, the Pooled Mean Group estimator designed for relatively higher T is not an appropriate method and I thus report results for fixed effects and GMM estimation from Section 3.4.4 on the Great Depression.

To have comparable estimates for the samples included, I set lags at zero and one. Unfortunately, estimates for further lags cannot be computed by the Pooled Mean Group estimator in several of the samples, as the method is sensitive to data availability in each cross section. Also, the Schwartz Criterion indicates repeatedly that short lags for all variables are suitable (mostly one), so this choice of lags seems appropriate. Still, especially in the samples with the cut-offs, where the year-on-year inflation rate was restricted to be under zero, due to a lot of non-consecutive observations some regressors had to be left out to obtain an estimate by the Pooled Mean Group estimator. There were also software limitations on the specifications of exogeneous regressors, due to which I leave out the level of GDP per capita from the PMG estimates. However, the Fixed Effects estimator allows for all regressors. Finally, the sample on Japan is not included as it does not have annual data—its quarterly data would require longer lags and would be difficult for comparison.

Discussion of results

On balance, the Pooled Mean Group estimator gives estimates close to those by the fixed effects model, and these results are in line with the coefficient estimates from the VECM's. The contemporaneous effect of inflation on GDP growth in most specifications (except the Great Depression) is slightly negative and statistically significant. The coefficient estimates on lagged inflation have overall less significance with one exception—the coefficient estimate on p_{t-1} for the after-gold-standard sample, which is slightly positive (0.037) and significant at 10% by the PMG.[34]

The different subsamples uncover interesting observations. The 'Full sample: Only deflation' sample does not show that inflation would start to affect output growth positively once it falls

[34]The negative and statistically significant contemporaneous estimate by the PMG for the full sample does not repeat itself in either the classical gold standard or after it. The reason is that there are observations that do not fall in either of the two subsamples. These are observations either before the classical gold standard or observations of countries that never were on the classical gold standard.

under zero. On the contrary, the contemporaneous estimates are slightly negative and significant both by PMG and FE. When the post-classical gold standard sample was restricted in inflation rates under zero in the same fashion, it again does not show a positive relationship between inflation and output growth—i.e., that deeper deflation would be associated with worse output growth performance. It should also be noted that this sample contains the Great Depression, but apparently many other observations of deflation offset its impact on the results of the sample.

Table 3.15: Panel Mean Group estimator and Panel Fixed Effects

	Full sample		Full: only deflation		Gold standard		After gold st.	
	PMG	FE	PMG	FE	PMG	FE	PMG	FE
constant	0.002	0.010	0.497***	−0.048	0.241	−0.207***	0.102**	0.029
	[0.895]	[0.220]	[0.007]	[0.188]	[0.136]	[0.001]	[0.011]	[0.173]
y_{t-1}	−0.002	−0.069***	–	−0.069	−0.253***	−0.284***	0.118*	0.003
	[0.969]	[0.333]	–	[0.202]	[0.000]	[0.000]	[0.087]	[0.971]
p_t	−0.068**	−0.062**	−0.11***	−0.089***	−0.021	−0.083*	−0.044	−0.062
	[0.022]	[0.023]	[0.005]	[0.004]	[0.689]	[0.052]	[0.365]	[0.108]
p_{t-1}	0.015	0.003	0.020	−0.004	0.108	−0.046	0.037*	0.006
	[0.330]	[0.839]	[0.464]	[0.800]	[0.287]	[0.279]	[0.096]	[0.714]
c_t	0.573***	0.627***	0.610***	0.851***	0.460***	0.471***	0.566***	0.708***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
c_{t-1}	0.062	0.114**	0.016	0.058	0.146***	0.157***	0.047	0.056
	[0.160]	[0.043]	[0.725]	[0.329]	[0.000]	[0.003]	[0.434]	[0.443]
m_t	0.056*	0.059**	0.134***	0.094***	0.128*	0.097**	0.083**	0.059
	[0.064]	[0.049]	[0.003]	[0.004]	[0.071]	[0.012]	[0.033]	[0.171]
m_{t-1}	−0.018	−0.004	−0.005	0.002	−0.059	0.051*	−0.068*	−0.008
	[0.569]	[0.800]	[0.869]	[0.914]	[0.182]	[0.068]	[0.066]	[0.689]
$oilp_t$	0.009***	0.007**	–	0.012	0.007	0.008	0.009***	0.010**
	[0.000]	[0.024]	–	[0.204]	[0.278]	[0.174]	[0.001]	[0.012]
$oilp_{t-1}$	−0.008***	−0.007**	0.004	0.000	−0.006	−0.006	−0.007**	−0.009**
	[0.005]	[0.031]	[0.481]	[0.951]	[0.505]	[0.192]	[0.013]	[0.020]
Ypercap	–	0.000	–	0.007	–	0.028***	–	−0.003
	–	[0.823]	–	[0.137]	–	[0.000]	–	[0.243]
EC term	−0.005	–	−0.271**	–	−0.009	–	−0.061***	–
	[0.539]	–	[0.012]	–	[0.146]	–	[0.009]	–
Observations	2171	2171	422	422	481	481	1452	1452
Schwartz Cr.	-3.66	-	-2.14	-	-3.25	-	-3.55	-
Adj. R^2	-	0.456	-	0.960	-	0.422	-	0.489

Note: Dependent variable: y_t. Numbers in brackets are p-values. Small-case variables are differences of natural logs of levels. Fixed effects: p-values based on White's heteroscedasticity and autocorrelation-corrected standard errors.

Table 3.16: Panel Mean Group estimator and Panel Fixed Effects (continued)

	After gold st.: Only deflation		Great Depression		Full ex Great Depr.	
	PMG	FE	FE	GMM	PMG	FE
constant	0.183*	0.084	0.608	–	0.000	0.012
	[0.067]	[0.122]	[0.318]	–	[0.986]	[0.161]
y_{t-1}	–	0.160*	−0.213*	−0.110*	−0.036	−0.101
	–	[0.062]	[0.089]	[0.055]	[0.517]	[0.156]
p_t	−0.142	−0.004	0.336***	0.291***	−0.065**	−0.061**
	[0.159]	[0.915]	[0.004]	[0.001]	[0.041]	[0.022]
p_{t-1}	–	−0.047	−0.152	−0.182	0.004	0.001
	–	[0.113]	[0.228]	[0.110]	[0.762]	[0.965]
c_t	0.552***	0.837***	0.578***	0.534***	0.559***	0.622***
	[0.000]	[0.000]	[0.000]	[0.001]	[0.000]	[0.000]
c_{t-1}	–	−0.251**	0.138	0.107**	0.081*	0.127**
	–	[0.015]	[0.325]	[0.030]	[0.070]	[0.025]
m_t	0.222***	0.042	0.270***	0.245***	0.059*	0.058**
	[0.006]	[0.241]	[0.005]	[0.006]	[0.073]	[0.046]
m_{t-1}	–	0.062*	−0.018	−0.005	−0.021	−0.002
	–	[0.089]	[0.836]	[0.919]	[0.496]	[0.901]
$oilp_t$	–	0.029**	0.047**	0.058***	0.005**	0.006
	–	[0.032]	[0.022]	[0.001]	[0.020]	[0.109]
$oilp_{t-1}$	–	−0.012	0.044*	0.065***	−0.010***	−0.010
	–	[0.294]	[0.063]	[0.001]	[0.001]	[0.002]
Ypercap	–	−0.008	–	–	–	0.000
	–	[0.176]	–	–	–	[0.742]
EC term	−0.250*	–	–	–	−0.007	–
	[0.051]	–	–	–	[0.419]	–
Observations	184	169	102	85	2069	2069
Schwartz Cr.	-2.16	-		-	-3.63	-
Adj. R^2	-	0.979	0.600		-	0.458

Note: Dependent variable: y_t. Numbers in brackets are p-values. Small-case variables are differences of natural logs of levels. Fixed effects: p-values based on White's heteroscedasticity and autocorrelation-corrected standard errors.

Another important observation comes from the last two subsamples—one only with Great Depression observations and the other with the full sample except the Great Depression. The Great Depression sample exhibits, as already shown earlier, a strong positive contemporaneous effect of inflation on GDP growth, which is highly statistically significant. When the full sample regression is run without the Great Depression, it stays very similar in regression coefficients to the full sample: the estimates on p_t are slightly negative by both PMG and FE and significant and the lagged coefficients are insignificant. This suggests that, indeed, the Great Depression stands out and is much unlike the rest of the sample. Therefore, there appears to be evidence that there was much more inflation-growth interaction during the Great Depression than the

part that can be described by the used demand and supply factors, especially by the collapse of money supply growth. There are two possible interpretations. First, there is ground for theories of self-perpetuating, perhaps expectations-based deflation and recession which were described as the 'kinked' DAD curve in Section 2.5. However, no other subsample in the present data set exhibits this relationship. This implies that very special circumstances must be at play if this mechanisms is to be operational. Second, money supply used to capture the shifts in aggregate demand may not be the correct measure and it may severely understate the true magnitude of the collapse in nominal demand during the Great Depression. This is of course possible and in this case, the deflation-recession link found for the Great Depression could still be ascribed to a drop in nominal demand and would not necessarily point to a true relationship between price inflation and growth.

Otherwise, the positive and highly statistically significant contemporaneous estimates on the effect of consumption growth and money supply growth on y_t are in line with expectations. The lagged effects are much smaller, in line with the results from the VECM's.

Comparison to other literature

The present analysis is significantly different from most other research since it includes both demand and supply control variables, contemporaneous and lagged coefficient estimates, several different short-run and long-run methods and uses various samples including two samples restricted only to deflation. The focus of most other research pieces is much more restricted and, most importantly, is not devoted to controlling for demand and supply factors. It is therefore not straightforward to find works directly suitable for comparison.

First and foremost, the present work showed VECM results for three panel samples (full sample, classical gold standard and after classical gold standard) and for one time-series sample (modern Japan). There is no other study which would follow this direction with large panel samples. Although Bordo and Redish (2003) and Bordo, Lane and Redish (2004) also used the VAR model, their attention was limited only to two and three countries, respectively, at the end of the 19th century. However, they conducted their analysis in levels, not in growth rates. They did not find evidence of a negative effect of prices on output. The present results are more general both in terms of time span, the number of countries, use of control variables (here I used also a supply-side control, unlike the mentioned authors) and in covering both the growth rates and long-run association of levels (within cointegration). The main result is that both in the three panel data sets and in the Japan time-series, there does not appear to be either long-run or short-run negative effect of inflation on output growth.

The ARDL and fixed effects results are somewhat more comparable and show a few interesting differences. Atkeson and Kehoe (2004) found a coefficient estimate of effect of inflation on GDP growth of 0.40 for the Great Depression and 0.08 for their entire historical sample. It should be stressed that the authors only use output growth and inflation without any other regressor and use only 5-year averages. That restricts their number of observations for the Great Depression to only 17. Here, annual data points to a possibly even higher coefficient estimate for the Great Depression (0.5–0.7) when not controlling for other variables as Atkeson and Kehoe do, and smaller (around 0.3) coefficient estimates when controlling for demand and supply variables. Still, the positive sign, relatively high economic magnitude and high statis-

tical significance is similar in the present study and in Atkeson's and Kehoe's work. However, in the full sample, using annual data and controlling for demand and supply factors produced statistically significant estimates of -0.068 and -0.062 (for ARDL and FE, respectively) in the present study. Atkeson and Kehoe report a positive estimate of 0.08 in the entire sample. Here, the difference can be due to two factors. The inclusion of money supply in the present work could have taken on itself some of the cases of recession and deflation, so that price deflation as such turns out to be much less associated with recession (or even the opposite, as the present coefficients show) than in Atkeson's and Kehoe's work where no control variables were introduced. Or, alternatively, the difference could be only due to the fact that Atkeson and Kehoe use 5-year averages which swamp the contemporaneous annual negative signs that I show here. The general feeling from the results, however, is in line with those of Atkeson and Kehoe.[35]

Borio et al. (2015) considerably expand the analysis of inflation and growth by adding certain control variables, but mostly of a financial-system flavour. They add other price measures such as asset prices and property prices to see whether they correlate better with output growth than CPI. Their work is therefore more focused on finding whether prices of narrowly defined assets do better in tracking GDP peaks and troughs than CPI, which they confirm. The part of their work that is comparable to the present one is a simple contemporaneous regression of output growth on inflation which produces a coefficient estimate for inflation of -0.01 (and not statistically significant) when asset prices and property prices are controlled for. Again, the present results show a negative and statistically significant coefficients of -0.068 and -0.062. This may suggest that the inclusion of money supply as a demand-side variable works more 'in favour of' price deflation than the inclusion of property prices and asset prices by Borio et al. In other words, money supply may work better and more generally in capturing the effects of swings in demand than narrower measures such as property prices or asset prices. This would make theoretical sense since aggregate demand is not closely linked to asset prices or property prices in all economies, while it more likely is to money supply. Alternatively, the difference between the results herein and by Borio et al. may be data-related. Borio et al. (2015) have more countries (38), which might be the reason why they could not use long data series on money supply and opted for alternative price measures instead. Finally, when restricting their observations to deflation, Borio et al. find a positive coefficient of 0.10 (though not significant) for the full sample. The present result is almost precisely the opposite with -0.11 by the PMG and -0.089 by the FE estimators, both highly significant. This difference again mirrors that from the full sample and with no restriction on inflation. The difference can be again due to the control variables or data.

Benhabib and Spiegel (2009) focused on potential non-linearities in the relationship between inflation and growth. Their main finding is that below certain inflation thresholds, the relationship is positive and significant. For their full sample, they either chose the threshold by the Hansen method, which yielded a value of inflation of 3.23%, or they imposed the threshold at the 50th percentile, which was 2.44%. They found coefficient estimates of inflation on growth of 0.30 and 0.34, respectively, and statistically significant below these thresholds. This finding

[35] Atkeson and Kehoe (2004, p. 99) write: "Our main finding is that the only episode in which there is evidence of a link between deflation and depression is the Great Depression (1929–1934). We find virtually no evidence of such a link in any other period."

is therefore opposite to those presented here. The reasons may be several. First, the thresholds are different—here, the threshold was imposed at 0% to precisely follow the definition of deflation. However, it does not appear likely that this would be the major reason, because if the relationship between inflation and growth is negative when inflation drops below zero, as the present findings suggest, it is not likely to jump to a positive coefficient of roughly 0.3 after expanding the sample to inflation rates of up to 2 or 3%. That would imply that there is a sharply positive relationship in the interval between zero and two or three percent, which is strong enough to change the results. Instead, the problem could be again in the control variables. Benhabib and Spiegel use a sample and method very similar to those of Atkeson and Kehoe (2004). That is, they use only inflation an output growth without control variables and work with 5-year averages. The authors suggest that 'our nonlinear specification might proxy for other missing variables that might be included in a more structural specification' (Benhabib and Spiegel, 2009, p. 788). However, it does not appear likely that non-linear specification alone could fully substitute missing variables. Rather, it could be the case that a non-linear specification without control variables may lead to spurious conclusions about the relationship between inflation and growth, which in fact takes on itself the effects of other variables, especially money supply. This is confirmed here where money supply growth has positive and significant effect on output growth in both of restricted samples with inflation below zero. This example reaffirms the importance of including control variables for valid results, which was one of the key objectives of the present chapter.

3.5 Summary

This chapter followed two main goals: to provide a comprehensive picture of the relationship between inflation and growth in a large data set, and especially to focus on filtering out the effects of demand and supply variables on this relationship in regression analysis.

The tools used in this chapter were more comprehensive than in other available studies. There are several major results. Generally, there does not appear to be evidence of short-run or long-run negative effect of deflation on output growth. The different methods such as VECM, ARDL or panel fixed effects are consistent in yielding this result. If there is an association, it is only in the Granger causality sense, i.e. in the combined statistical significance of past values of inflation in predicting future output growth in some of the samples. However, these coefficient estimates of effect of price growth on output growth are negative. In addition, some of the specifications such as the contemporaneous effect repeatedly yield small but negative and statistically significant estimates of effect of inflation on growth. The reason for this finding, unlike in other studies, may be the addition of control variables, mainly money supply growth, which has an important effect on output growth that could otherwise be ascribed to price growth. Second, the Great Depression stands out as the only episode in the sample with both a statistically significant and economically important (positive) contemporaneous relationship between inflation and output growth. Adding money supply growth and other variables does reduce the coefficients, but they stay positive. Third, Japan's economy in the 1990s and 2000s does not show evidence—based on the VECM and other observations—that slow economic growth was associated with deflation. It rather seems that Japan's slow growth has been

due to demographics and is similar to the European experience. Fourth, restricting inflation observations to only negative values does not produce a major change in the relationship.

A key implication for theory is that there is a single case—the Great Depression—where there is a tangible link between recession and deflation, even after controlling for demand and supply factors. That would suggest that there might be circumstances under which price deflation per se, on top of money supply contraction, affects prices negatively. However, these circumstances seem to be very rare.

There are certainly caveats to note. The analysis used readings of actual inflation and deflation which should not be mixed with inflation and deflation expectations. As explained in the previous chapter, the choice of either actual values or expectations has trade-offs, and the choice of actual values means that expectation-based theories cannot be fully assessed. The lagged values of inflation or even the contemporaneous (annual) inflation could be proxies for expectations, but without certainty. Also, I did not analyze modern panels since these have scarce deflation expectations and any results would rather stem from the comparison between high and low inflation than inflation and deflation. But the reliance on long historical samples does not imply that the coefficient estimates from the full sample should be automatically extrapolated to the present time.

Appendix

3.A Data Definitions and Sources

The following are the definitions and sources of variables used in Chapter 3.

Prices

Prices refer to the Consumer Price Index where possible since it is today the generally preferred measure of price change by most economists and organizations. I use the GDP deflator where the CPI is unavailable, which is mainly the case of the 19th-century observations.

Prices before 1980 are from Atkeson and Kehoe (2004) and Jordà et al. (2017), except for Australia, Denmark, Switzerland and Belgium which are taken from Bordo (2018). Prices from 1980 onwards are from IMF (2018) and World Bank (2017) for all countries.

Quarterly seasonally adjusted data on Japan in 1990–2015, used in Section 3.4.5, are from Japan Statistics Bureau (2018).

Output

Output is defined as GDP or GNP in constant currency. Data on output before 1980 is from Atkeson and Kehoe (2004), Jordà et al. (2017), Mitchell (2003) and Smits et al. (2009), except for Australia, Belgium, Denmark and Switzerland which is taken from Maddison (2010). GDP from 1980 onwards is from Maddison (2010) and World Bank (2017) for all countries.

Quarterly seasonally adjusted data on Japan in 1990–2015, used in Section 3.4.5, are from IMF (2018).

Consumption

Consumption is defined as private consumption in constant currency. The data is from Jordà et al. (2017) except for Argentina, Brazil and Chile, which are from the World Bank (2017).

Investment-output ratio

The investment-output ratio is the fraction of gross investment and GDP or GNP, both in current prices. The data is from Jordà et al. (2017) and from the World Bank (2017).

Interest rates

Interest rates used are the short-term (money-market) interest rate and the long-term interest rates, which is the yield to maturity of a 10-year government bond. The data until 2013 is from Jordà et al. (2017) and from 2014 until 2015 is from the OECD (2016). The exception is data for Argentina, Brazil and Chile, which are from the IMF (2018) for their whole time span.

Unemployment

Data on the unemployment rate in Japan in Figure 3.12 are from the OECD (2016).

Per capita variables

GDP per capita in 1990 US dollars is from Inklaar (2018). GDP per capita in local currencies and other per-capita statistics in local currencies are from Jordà et al. (2017) and the World Bank (2017).

Oil Prices

The oil price series (1861–2015) represents average annual prices of oil per barrel in US dollars as retrieved from British Petroleum (2018). The series is composed of three standardized contracts that were traded on commodity markets throughout the time span of the series: 1861–1944: 'US Average'; 1945–1983: Arabian Light; 1984–2015: Brent.

Quarterly data for 1990–2015, used in Section 3.4.5 on Japan, are Brent oil prices from Bloomberg (2018) and seasonally adjusted using X13-SEATS-ARIMA.[36]

Money supply

Different measures of money supply were used according to data availability for each country. For Argentina, Belgium, Brazil and Chile, money supply represents the M1 aggregate or 'narrow money', which encompasses coins, currency notes and demand deposits. For Canada, Finland, France, Italy, Japan, Netherlands, Norway and Portugal, money supply represents M2, which encompasses M1 plus savings deposits and the money market. For Australia, Denmark, Germany, Spain, Sweden, Switzerland, United Kingdom and United States, money supply represents M3, which encompasses M2 plus large time deposits and money in institutional funds.

The data comes from Jordà et al. (2017), Bank of England (2018), Bloomberg (2018), Bordo (2018), Federal Reserve Bank of St. Louis (2018) and Swiss National Bank (2018).

Quarterly data on Japan in 1990–2015, used in Section 3.4.5, are M2 data from the IMF (2018) and seasonally adjusted using X13-SEATS-ARIMA.

[36] I thank Martin Janíčko for provision of the data in seasonally adjusted form.

3.B Data Availability

Table 3.17 lists the span of annual data series for each country. (The starting dates of the series are as they were retrieved from their source, but where first differencing was needed, the series used in the regression starts a year later.) There are minor interruptions in the data series, usually a sporadic year of missing data for the pre-World War II era.

Table 3.17: Initial years of data series

Country	Prices	Output	Consumption	Inv./Output	Short-term int. rate	Money supply
Argentina	1884	1884	1960	1960	1980	1884
Australia	1861	1821	1901	1870	1870	1870
Belgium	1835	1846	1913	1900	1870	1877
Brazil	1880	1861	1960	1960	1948	1890
Canada	1870	1870	1871	1871	1934	1871
Chile	1860	1820	1960	1960	1976	1950
Denmark	1816	1820	1870	1870	1875	1870
Finland	1870	1870	1870	1870	1870	1870
France	1820	1815	1870	1870	1870	1870
Germany	1820	1850	1870	1870	1870	1870
Italy	1861	1862	1870	1870	1870	1870
Japan	1870	1870	1874	1885	1879	1870
Netherlands	1870	1820	1870	1870	1870	1870
Norway	1850	1830	1870	1870	1870	1870
Portugal	1833	1833	1910	1953	1880	1870
Spain	1812	1849	1870	1870	1880	1874
Sweden	1804	1804	1870	1870	1870	1871
Switzerland	1870	1850	1870	1870	1870	1880
United Kingdom	1804	1830	1870	1870	1870	1804
United States	1804	1804	1870	1870	1870	1870

The last year of all series is 2015. There are minor exceptions especially for the money supply where some historical series starting in the 19th century are available until 1997 or 2013 and do not yet have continuing values for later years.
The oil price series starts in 1861 and is identical for all countries. As a result, it is omitted in the table.

3.C Unit Root Tests and Cointegration Tests

Table 3.18: Tests for unit roots in panel data: p-values

Series	Levin, Lin & Chu	Im, Pesaran & Shin	ADF-Fisher χ^2	PP-Fisher χ^2	Lags based on BIC	Obs.
			Full sample			
Levels						
GDP	0.496	1.000	1.000	1.000	0 to 4	2176
Prices	1.000	1.000	1.000	1.000	0 to 3	2173
Consumption	0.802	1.000	1.000	1.000	0 to 2	2183
Money	1.000	1.000	1.000	0.507	0 to 2	2175
1st differences						
GDP	0.000	0.000	0.000	0.000	0 to 3	2164
Prices	0.000	0.000	0.000	0.000	0 to 2	2167
Consumption	0.000	0.000	0.000	0.000	0 to 1	2168
Money	0.000	0.000	0.000	0.000	0 to 1	2169
			Classical gold standard			
Levels						
GDP	1.000	1.000	1.000	1.000	0 to 4	487
Prices	1.000	1.000	0.988	0.996	0 to 4	477
Consumption	0.750	1.000	1.000	1.000	0 to 4	486
Money	1.000	1.000	1.000	1.000	0 to 1	492
1st differences						
GDP	0.000	0.000	0.000	0.000	0 to 2	467
Prices	0.000	0.000	0.000	0.000	0 to 4	467
Consumption	0.000	0.000	0.000	0.000	0 to 3	477
Money	0.000	0.000	0.000	0.000	0 to 1	478
			After classical gold standard			
Levels						
GDP[a]	0.000	0.955	0.944	0.970	0 to 4	1456
Prices	0.906	0.996	0.122	0.713	0 to 3	1454
Consumption[a]	0.059	1.000	1.000	1.000	0 to 1	1463
Money	0.996	1.000	0.103	0.113	0 to 2	1453
1st differences						
GDP	0.000	0.000	0.000	0.000	0 to 3	1445
Prices	0.000	0.000	0.000	0.000	0 to 2	1448
Consumption	0.000	0.000	0.000	0.000	0 to 1	1451
Money	0.000	0.000	0.000	0.000	0 to 2	1446

Null hypothesis: Unit root in panel data. Data was tested in natural logarithms. Levin, Lin & Chu test assumes common unit root process. Im, Pesaran & Shin test, ADF-Fisher χ^2 test and Phillips-Peron-Fisher (PP-Fisher) χ^2 test assume individual unit root processes. BIC stands for Bayesian Information Criterion. Price data exclude years where inflation is outside [-20%, 20%] annual change. The number of observations refers to the Levin, Lin & Chu test. [a] Additional tests (Breitung, Hadri) indicate presence of unit root.

Table 3.19: Tests for unit roots in time series: p-values

Series	Augmented Dickey-Fuller	Phillips-Perron	Lags based on BIC	Obs.
		Contemporary Japan		
Levels				
GDP	0.212	0.227	0	103
Prices	0.003	0.003	1	102
Money	0.999	0.928	4	99
1st differences				
GDP	0.000	0.000	0	102
Prices	0.000	0.000	0	102
Money	0.014	0.000	3	99

Quarterly data: 1Q1990–4Q2015. Null hypothesis: Unit root present. Data was tested in natural logarithms. BIC stands for Bayesian Information Criterion. The number of observations refers to the Augmented Dickey-Fuller test. All readings of inflation are in the [-20%, 20%] range. No exclusions of outliers were made.

Table 3.20: Johansen-Fisher test for cointegration

Subsample	Johansen-Fisher test (p-values)				Max. lag length	Obs.
	0 coint.	$\leq$ *1 coint.*	$\leq$ *2 coint.*	$\leq$ *3 coint.*		
Full sample	< 0.001	0.001	0.758	0.997	3	2205
Classical Gold Standard[a]	< 0.001	< 0.001	0.444	0.030	2	510
After Classical Gold Standard	< 0.001	0.001	0.094	0.963	2	1484
Contemporary Japan	0.068	0.252	0.740	n.m.	2	101

Null hypothesis: up to 0, 1, 2, or 3 cointegrating relationships, respectively. Johansen-Fisher test assumes linear trend. Variables included in panel data set are GDP, Prices and Consumption. Maximum lag length determined by Bayesian Information Criterion in a corresponding VAR model in levels; extended in case of autocorrelation. Data was tested in natural logarithms. Price data exclude years where inflation is outside [-20%, 20%] annual change.

[a] Pedroni and Kao tests do not reject the hypothesis of cointegration. Two cointegrating relationships are chosen.

Chapter 4

Sector Analysis in the Czech Republic, Japan and the United States

4.1 Motivation

Chapter 3 has shown the possibilities but also the limitations of the macroeconomic approach to deflation. Studies that have tried to assess the relationship between economic growth and price growth suffer from several drawbacks. Above all, episodes of deflation in the aggregate CPI or in the GDP deflator have been scarce in the past few decades. When deflation appeared, it was usually very transitory. For example, Borio et al. (2015, p. 48) acknowledged this problem when they inspected 38 countries and concluded that "We have only a few episodes of persistent deflation in the postwar period." Even in Japan, as we showed in Section 3.4.5, the observed CPI deflation has been close to zero and difficult for drawing major conclusions. Therefore, studies on deflation have had to rely on historical data, often before World War I. Whatever these studies show, their conclusions may be criticized as having limited relevance for the modern day, because they are based on old observations.

In fact, there could be much more price variation in modern data, including sizable price decreases, yet this variation may be hidden 'inside' the economies and aggregate statistics—by definition—cannot account for it. As a result, we know very little about whether firms and consumers in sectors of the overall economy encounter significant price decreases (if any at all), where they come from and how they are linked to output growth.

In this chapter, we propose a different approach. Instead of using aggregate data on GDP growth and inflation, we focus on sector data on production growth and price growth. Specifically, we use national accounts input-output data for the Czech Republic, Japan and the United States, which contain readings on production, gross value added, prices and other variables in several dozen sectors of each respective economy. We believe this shift closer to microeconomics can remedy the main disadvantages of aggregate data sets. We are also convinced that this shift is well justified theoretically, although there are considerable costs that we discuss below. The particular advantage is that the sector approach provides us with many more modern-day observations of price decreases and with much higher variation of price data than what can be

An earlier version of this chapter is forthcoming as Ryska, P. and Sklenář, P. (2018): Deflation and Output across Sectors: Results for the Czech Republic, *E&M Economics and Management*.

provided by aggregate data. After all, aggregate data are just weighted averages of all available components and we suggest that it is also worth using more fully these components.

Consider, for example, the price trends in selected sectors of the Czech economy over 1993–2015 in Figure 4.1. While the overall price deflator (broken line) shows continuous growth, there are sectors that saw their output price practically flat or even significantly down over the period. By contrast, there are sectors that saw their output prices skyrocket by hundreds of percent. The difference in trends is even more visible when we cut off the relatively high-inflation 1990s and look at the trends only starting from the year 2000 in Figure 4.2. Some sectors sold their products at lower prices in 2015 than in 2000.[37] For illustration, in Japan, more than *half* of all sectors reported by the Japan Cabinet Office (2017) were in cumulative deflation over the period 1995–2015.

If price development is important in shaping consumers' and firms' choices about purchases and in determining firms' output, as some theories assert, the price changes in sector data with much higher dispersion than aggregate data could help empirically clarify this hypothesis. We think this approach is novel: we do not know of any other study that would analyze deflation and growth using sector data. Obviously, we do not propose this approach as a substitute to aggregate data, but rather as a complement that can enrich our knowledge.

We find that in the long run, sectors with deflation or below-average inflation are associated with above-average output growth, which could be a reflection of supply-driven deflation. In panel data, we do not find evidence that sector deflation would lead to a drop in quantity demanded, after controlling for demand and supply factors. We also stress below that due to the nature of sector data, we think our results have implications for economic theory, but less so for economic policy.

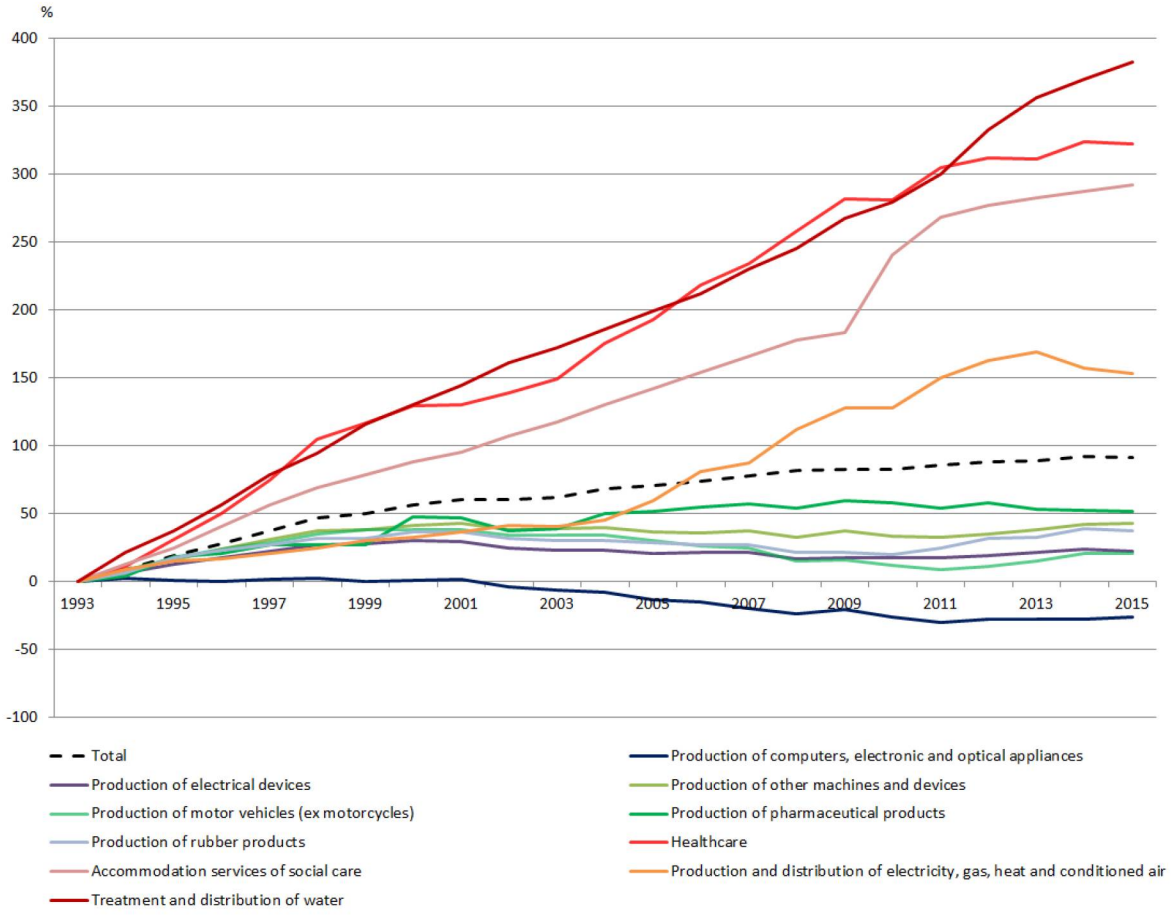
This chapter proceeds as follows. In Section 4.2, we discuss the possibilities and limitations of shifting more towards microeconomics in analyzing deflation. In this section, we pay special attention to the justification of a more microeconomic approach to deflation. In Section 4.3, we present our sector data from national accounts. We first show some descriptive statistics in Section 4.4. We then look into long-run cross-section links between output growth and price growth in Section 4.5. Section 4.6 then looks more closely on panel data. Here, we first address the problem of endogeneity in estimating demand equations and we then use different methods and samples to explore whether sector deflation has an effect on quantity demanded. Section 4.7 provides discussion and Section 4.8 summarizes the chapter.

4.2 Moving Closer to Microeconomics: Possibilities and Limitations

The use of sectoral data stands halfway between macroeconomics and microeconomics: the data still aggregates consumers and firms, but the level of aggregation is over industries (sectors), not over the economy as a whole. Shifting focus from macroeconomic data to sectoral data involves a number of advantages and disadvantages and raises some questions. The key question is whether there are good enough reasons why a macroeconomic phenomenon such deflation

[37] Out of 86 sectors reported by the Czech Statistical Office (2017) in national accounts, 11 had lower output prices in 2015 than in 2000. We show only selected ones in Figure 4.2.

Figure 4.1: Cumulative price change in selected sectors: Czech Republic 1993–2015



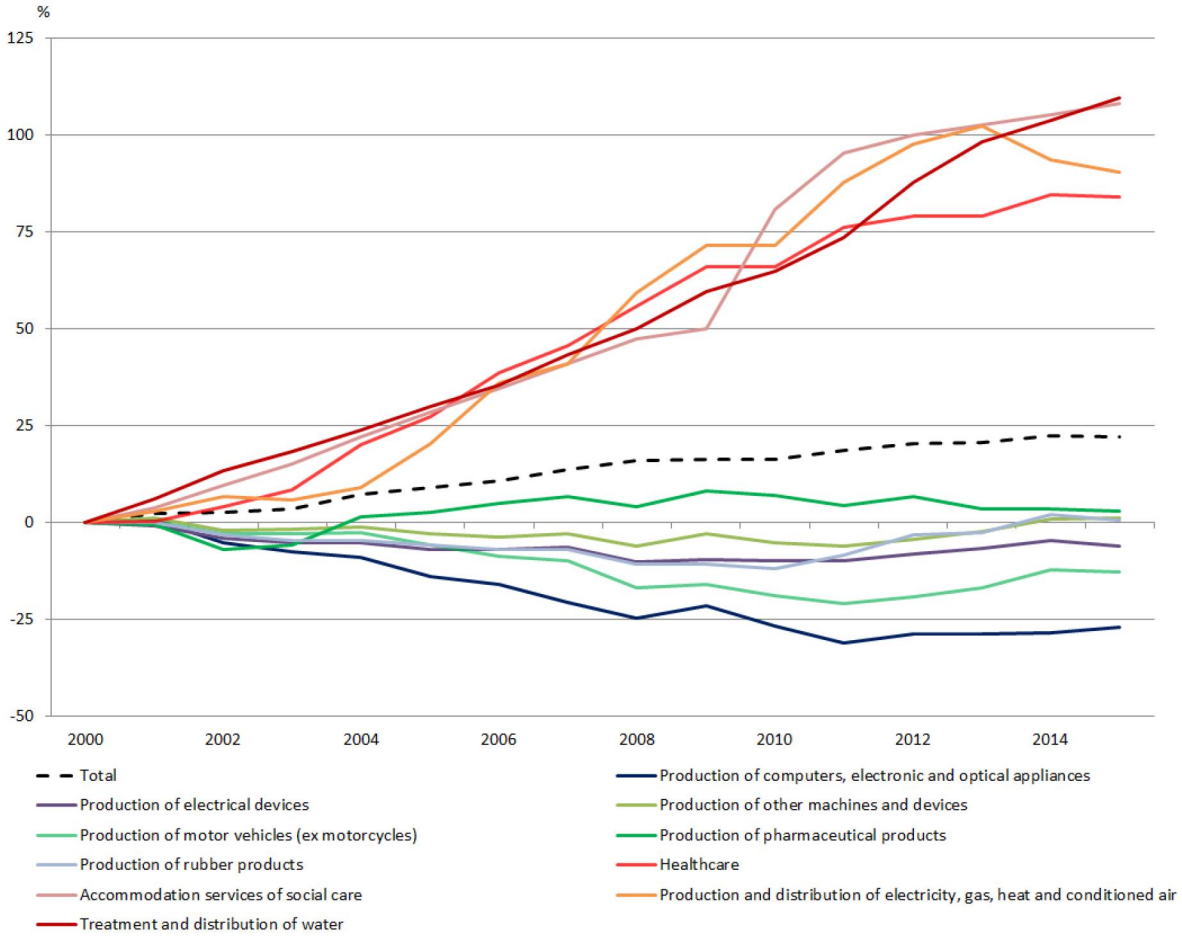
Source: Czech Statistical Office (2017), own computations.

(or inflation, more generally) could be thought of more microeconomically and analyzed on disaggregated data. In this section we first argue that theories of recession and deflation are in their core based on microeconomic reasoning, which makes them testable on disaggregated data. Next, in support of our approach, we provide examples of both earlier and recent literature which uses disaggregated data to answer macroeconomic questions. Finally, we provide an overview of advantages and disadvantages of the sectoral approach as compared to a traditional macroeconomic (aggregated-data) approach.

4.2.1 Microeconomic Foundations of Deflation-Recession Theories

There are four main theories detailed in Section 2.3.1 why deflation should be linked to recession. Although these theories are used as macroeconomic arguments, at least three of them have microeconomic foundations. Consider first the argument about postponement of consumption and investment. The crux of the argument is that consumers and firms postpone spending when deflation makes current purchases relatively expensive compared to prices that they expect in the future. As a result, there must be concrete classes of goods and services that will be affected by the postponement of spending due to these goods' and services' price deflation. Interestingly,

Figure 4.2: Cumulative price change in selected sectors: Czech Republic 2000–2015



Source: Czech Statistical Office (2017), own computations.

Krugman's (1998) article, which is one of the key contributions to the postponement theory, emphasizes consumer choice and allows the consumer in one of his models to make separate choices over different classes of goods. This supports our approach: we empirically investigate the relationship between output and prices on disaggregated sector data that capture consumers' and firms' choices over different goods and services.[38]

[38]There is also another way how to look at the postponement argument and show its proximity to microeconomics. Theories on deflation work with the Fisher equation and state that the real interest rate is co-determined by an economy-wide inflation rate π. If inflation drops or turns into outright deflation, consumers and firms face a higher real interest rate. We suggest that what really matters to the firm is not an economy-wide inflation rate π, but a firm-specific rate—we may denote it π_i— which captures the price inflation or deflation of the firm's output. The idea of the real interest rate is to adjust the nominal interest rate by a rise or fall in the purchasing power of money. But this is valid only if the firm in question really encounters inflation or deflation in its sales. The burden of paying the nominal interest on debt is alleviated if output prices rise and therefore deduct from the nominal interest rate. Inflation 'pays for' the firm. On the contrary, the firm's burden grows with deflation which adds on top of the nominal interest rate. It is not crucial for the firm whether the price inflation or deflation that it faces in its product market prevails also in the whole economy. What rather matters is its own output price.

The second deflation-recession argument on nominal rigidities is, in our view, also rather microeconomic. The crux of the argument is that firms are unable to pass decreasing output prices on to their input prices, thereby finding themselves in a profit squeeze. The microeconomic nature of the argument lies in the fact that the profit squeeze only happens if the particular firm's output price deflates. Firms find themselves in a profit squeeze because nominal demand for their product decreases, irrespective of whether this is due to an economy-wide drop in nominal demand or just product-specific (or sector-specific) drop in demand. In any case, the inability to adjust, which is the crux of the argument, is testable on disaggregated data. The microeconomic nature of nominal rigidities is also illustrated by the fact that studies trying to assess its validity have used purely microeconomic data sets on individual firms (e.g. Carlton (1986), Seltzer (2010) as described in Section 2.3.1.2).

The third deflation-recession argument, Fisher's (1933) debt-deflation, is a special case of nominal rigidities and again can be shown to have microeconomic foundations in its core. It states that an over-indebted firm is forced to sell assets and may go bankrupt if it is pressured by deflation of its product price. Admittedly, the ensuing spiral effect where selling of assets by one firm exerts deflationary pressure on other firms is already macroeconomic because it involves economy-wide interactions. However, it changes little about the fact that a firm will suffer from debt-deflation only if *its* product price deflates. This again makes it testable on disaggregated data.

Unlike these three arguments, the fourth argument from Section 2.3.1—potential ineffectiveness of standard monetary policy under deflation—is purely macroeconomic. However, this argument is of practical, economic policy nature, and we are most interested in testing the first three theoretical arguments.

Our take from the deflation-recession theories is that while they have been developed for macroeconomic reasoning, they have their microeconomic foundations and could be tested on a disaggregated level. If, for example, deflation should lead to postponement of consumption and therefore to a drop in output, this must be demonstrated in deflation of and the postponement of consumption of *concrete* goods and services and therefore in the drop of their output. Prices of goods and services usually have common trends within their classes, which justifies the use of sector data. This is why, for instance, Dhyne et al. (2005, p. 4) speak of 'sectoral inflation rates' and 'product-specific inflation'. Similarly, Burdekin and Siklos (2004, p. 7) emphasize the need to look at 'deflation in certain key components of aggregate prices', as opposed to only looking at 'headline price indices'. In short, we do *not* aim to redefine inflation and deflation and shift the meaning of these terms from the macroeconomic level to the microeconomic level. We believe, however, that for the sake of analysis, we can use terms 'sector inflation' and 'sector deflation' in order to succinctly describe price movements in sectors, similarly to authors cited above.

One counter-argument is that macroeconomic theories of deflation and recession hinge on overall deflation expectations—i.e., that consumers postpone consumption based on their expectation that the aggregate price level will fall. That such an overall expectation about the general price level exists is obviously possible. However, it is not mutually exclusive with the assertion that consumers mainly link their consumption choices to the price of the goods in question. In other words, if the theory about postponement is correct, it would likely arise

from a series of microeconomic decisions to postpone consumption of certain goods and services because *their* prices are falling and expected to fall. These decisions then make up the aggregate result and if there are enough postponement decisions, aggregate consumption will fall. Thus, we see a drop in overall consumption as a possible result of consumer choices over many classes of goods and prices. This is why it is relevant to look into prices and output of sectors of an economy.

If we reverse the perspective from the buyers (consumers) of goods and services to their sellers (producers), it would make even more sense to look at the relationship between the firm's output and its output price than to consider just the overall price level. The so-called 'islands model' of business cycles by Lucas (1972, 1973, 1975) illustrates the idea that what matters to production is the 'price vicinity' of producers and workers, while the overall price level is a more distant and uncertain variable. However, we devote more space in this chapter to the demand side.

To sum up, macroeconomic theories of deflation and recession have their microeconomic, disaggregated interpretations which are testable on respective data. In our opinion, the macroeconomic and microeconomic interpretations are not mutually exclusive and are not at odds with each other. They are rather complementary. If theories assume that decisions of consumers and firms are seen in aggregates, they must also be seen at least in some components that make up these aggregates.

4.2.2 Literature Focusing on Alternative Price Measures

Several studies, both past and relatively recent, have focused on individual, sector-level or relative prices to draw conclusions for macroeconomic theory. Carlton (1986) and Dhyne et al. (2005) have shown on American and European data, respectively, that there are a lot of firm-level and sector-level price decreases and that there is little asymmetry between upward and downward price adjustments. This is an example of micro-level focused works, which however go to the heart of the nominal-rigidities argument and may provide answers for macroeconomic theory.

Ball and Mankiw (1995) use sector-level, disaggregated data for the US economy in 1949–1989 to explore whether relative price changes may be connected to overall price changes and shifts in the Phillips curve. The authors stipulate that in the presence of menu costs, small intended price changes do not materialize while only large intended price changes are realized by firms. As a result, even if the money supply does not change, there might be shifts in the overall price level only due to the asymmetry in intended price changes and the presence of menu costs. Ball and Mankiw conclude that disaggregated data are better at shedding light on some macroeconomic questions (such as explaining certain recessions of the US economy) than traditional aggregate data.

Moving closer to deflation, a very recent study by Eichengreen et al. (2016) argues in favour of using alternative price measures as opposed to only using CPI: "The price index utilized may not be the one relevant to the consumption and investment decisions of agents; consumers care about consumer prices, while producers presumably care about producer prices." (p. 2–3) Based on this reasoning, Eichengreen et al. add the Producer Price Index (PPI) as an alternative measure of prices and use it along with CPI in their regressions. The reasoning used

by Eichengreen et al. about the relevance of price indices supports our case: sector data, which cover both consumer and capital goods, allow much more precision in linking consumption and investment decisions with the respective prices than what would be the case with aggregate indices.

In sum, this overview shows that while our approach to studying deflation and output growth using sector data is novel, the disaggregated approach as such has already become a part of macroeconomic literature. Especially, the overview demonstrates that the disaggregated approach is not at odds with analyzing macroeconomic phenomena.

4.2.3 Overview of trade-offs

Using disaggregated data has both advantages and disadvantages and we summarize our view on these in Table 4.1, where we categorize the debate into three areas: data, identification and relevance of results. We discuss each of these three areas below.

Table 4.1: Sector data vs. macro data: Comparison

Area	Feature of data	Macro data	Sector data
Data suitability	Modern-day deflation observations	Scarce	Frequent
	Variation of data	Low	High
Identification	Availability of demand shifters	Sufficient	Poor
	Availability of supply shifters	Poor	Sufficient
Relevance of results	Implications for theory	Potentially high	Potentially high
	Implications for monetary policy	Potentially high	Limited

Data suitability

For the purpose of studying deflation, the existing empirical research has a clear data-related disadvantage. Most of the studies included in the summary of empirical articles in Table 2.1 use only aggregate macroeconomic variables, most often the GDP and CPI inflation. This causes an undesired trade-off: the aggregate annual data do not show almost any years with deflation in the last decades for most developed economies. For the Czech Republic, too, the aggregate price deflator shows only one year with deflation in the period 1993–2015. When researchers want to use aggregate data and learn more about deflation, they have to use pre-World War I data which are rich in observations of deflation. This was the motivation for Bordo and Redish (2003), Bordo, Lane and Redish (2004) and Beckworth (2007) who all focused exclusively on the classical gold standard period.

The results are then vulnerable to the criticism they are based on old observations which may have little relevance for today for a number of reasons. To name a few, there has been a 'monetary regime change' with the transition from metallic standards to the fiat money regime; there are very different levels of private and public debt; there is dramatically more financial

intermediation, etc. For example, Schularick and Taylor (2012) show on a sample of 14 countries that the loan-money ratio steeply accelerated its growth rate after World War II, making the level of indebtedness and leverage in the financial system much higher than in the classical gold standard period that the aforementioned studies use to analyze deflation. This may render studies based on the classical gold standard obsolete.

Another, more subtle problem with macroeconomic data on prices is their low variation. For example, Japan is one of the few developed countries that provides modern-day observations of deflation on the aggregate level. However, all annual observations of deflation except for one fall into the interval (-1%, 0%). This low variation may cause high standard errors of coefficient estimates and insignificant results.

By contrast, sector data have none of these drawbacks as they (1) contain numerous episodes of sector deflation from *recent* periods, and (2) have much higher variation of observations.

Identification

Similarly to macroeconomic analysis, one of our goals is to separate deflation arising due to shifts in certain supply factors from deflation arising from shifts in major demand factors and see if there is a further link between price growth and output growth. This is tantamount to the classification of 'good', 'bad' and potentially also 'ugly' (self-perpetuating) deflation as coined by Bordo and Redish (2003). Deflation is of the good type if is associated with rising output. In particular, good deflation occurs when firms invest to decrease unit costs and increase output. Bad deflation is associated with falling output. In this case, deflation results from decreasing nominal demand, which cannot be immediately passed on to lower prices of inputs. We are however particularly interested—as in the macroeconomic chapter—in exploring whether data reveal a potential third type of deflation, which feeds on itself and which would be present even after controlling for usual demand and supply factors.[39]

The possibility of identification of demand and supply curves is different with sector data than with macro data. Sector data generally contain supply-side variables such as the amount of inputs in production (intermediate inputs, employment) and their prices. This allows us to imitate shifts in supply curves better than in the macro setting where we have to rely on a common input in all sectors. By contrast, it is difficult to find a variable that would capture the shifts of demand curves in particular sectors. While on the macroeconomic level money supply can represent nominal demand for a given economy, it is impossible to have an analogous variable that would vary by sectors. In sum, the sector level does relatively better in providing supply shifters, but does worse in providing demand shifters.

Relevance of results

There is a key difference in how potential results from the analysis of sector data can be interpreted as compared to macroeconomic data. We are of the opinion that analysis of sector data can yield potentially important implications for economic theory, but less so for monetary policy. We see two reasons for this.

[39] See Chapter 2 for detailed discussion on types of deflation.

First, the very fact that we use sector data reduces the usability of results for the purposes of monetary policy since neither the goals nor the tools of monetary policy are aimed at specific sectors of the economy. For example, findings about the relationship between sector inflation and sector output growth may not have any direct policy implications as sectoral developments are usually not an input in the making of monetary policy. The implications may be rather indirect—i.e., through impact of the results on economic theory.

Second, sector data from national accounts provide a supply-side view on production and prices. To the extent that, mainly in the case of the Czech Republic, a large part of production in some sectors is exported, these products will have a larger weight in domestic production than in the CPI. Since the key price measure targeted by monetary-policy makers is the CPI, results from the sector analysis should not be directly extended to monetary policy.

Therefore, while analyses of aggregate macroeconomic data have, by definition, potential implications for both theory and policy, sector analysis is in our opinion more relevant for theory than policy. We believe that this distinction is important. Our goal is to cast more light on the core of *theories* of deflation and recession.

4.3 Data

We use national accounts annual data on sectors of production for the Czech Republic, Japan and the United States. The number of sectors and years together with sources of the data is summarized in Table 4.2.

The common feature of samples from three different countries is that they all have data on several basic variables: sector output prices (implicit price deflator), sector output volume (i.e, real output) and one or more measures of volume of inputs in production and their corresponding prices. Czech and US data also provide gross value added (GVA) in real terms, while for Japan this variable is unavailable.

Our primary interest lies in sector data on the Czech Republic. They provide the richest view on the economy from the point of view of cross-section price movements because they contain 86 sectors, more than US data (40 to 65 depending on sample) and much more than Japanese data (29), as seen in Table 4.2.[40] However, the Czech economy is a small open economy with a high share of exports and imports on GDP. As a result, both input and output prices reported below might have been pushed lower by the strengthening of the Czech koruna against the euro and the dollar over the period in question (1993-2015). This is why we want to check any potential results with countries with a different position in international trade. Both the United States and Japan are large and relatively closed economies. The ratio of exports to GDP stands at c. 80% for the Czech Republic, while it is at 16% for Japan and at 12% for the United States. Thus the latter two countries may serve well for comparison.

Japan and the United States represent a certain trade-off for our analysis. Japan is known for its very low inflation and occasional deflation since the 1990s, and therefore is highly interesting

[40] From the original data sources we have excluded subtotals so as to avoid counting sectors twice. For example, several sectors producing goods are added up and reported under a subtotal for 'manufacturing'. We therefore only retain the individual sectors, not the manufacturing subtotal. Also, on rare occasions we have excluded sectors which had long series of missing observations.

from the point of view of sectoral price movements. Our data from the Japan Cabinet Office (2017) start in 1994, which is one year before Japan first recorded aggregate consumer-price deflation. The sample therefore captures the most discussed period in modern Japan. A more explicit advantage is that Japan spent practically this whole period with the zero-lower bound binding, which makes it a potentially interesting case in assessing the link between price growth and output growth. However, the Japanese data set includes only 29 sectors, so the sample is relatively smaller. Conversely, the US data from the Bureau of Economic Research (2018) lack any distinct deflationary or ultra low-inflationary period as the US has consistently maintained above-zero aggregate inflation after World War II. However, the USA data sets have both significantly more sectors and years than that for Japan. We include three samples for the US that differ in the number and definitions of sectors.

An important feature of our data is that it does not cover only sectors producing for final consumption, but also sectors upper in the production chain—i.e., sectors producing capital goods and intermediate inputs. As a result, firms' output does not mean only consumer goods bought by consumers, but also capital goods bought by other firms.

Table 4.2: Sector data: samples used

Country	Years[a]	No. of sectors	No. of observations	Sources
Czech Republic	1994–2015	86	1892	Input-output data: Czech Stat. Office (2017) Credit, money supply: CNB ARAD (2018)
Japan	1995–2015	29	609	Input-output data: Japan Cabinet Office (2017) Credit, money supply: FRED (2018)
USA Sample A	1999–2015	63	1071	Input-output data: BEA (2018) Credit, money supply: FRED (2018)
USA Sample B	1948–2017	40	2800	Input-output data: BEA (2018) Credit, money supply: FRED (2018)
USA Sample C	1964–2017	65	3445	Input-output data: BEA (2018) Credit, money supply: FRED (2018)

[a] Since the interest lies in changes of variables, the fist time period of the initial series is lost due to differencing. We therefore state the years for which we have growth rates.
There are minor cases of missing data for certain variables or sectors. For example, data on employment only start in 1995 in the Czech Republic.

4.4 Descriptive Statistics

In this section we focus on basic statistical relationships between the sign of price change (sector inflation/deflation) and the sign and growth rate of production or GVA. In particular, we focus on whether declines in production are associated with deflation. In our sample for the Czech Republic, positive price growth prevails and accounts for 80% of all observations (see Figure 4.3). At the same time, approximately three fifths of observations have positive growth of production and gross value added. As a result, roughly half of observations lie in the top-right quadrant in Figure 4.3.

In Table 4.3, we report the comparison of growth in production and gross value added under

increasing versus decreasing prices. We also visualize the comparisons with density graphs in Figure 4.4. Out of observations with price deflation, 69.7% recorded positive growth in real production, while the corresponding percentage for observations with inflation is only 58.8%. This is also reflected in the averages: the average growth rate of production during episodes of price deflation is 5.47%, which is considerably higher than the average growth with inflation (2.85%). Therefore, this preliminary observation shows that sector deflation is not linked to subpar output growth. To check this finding, we also ran a formal test of equality of means. As seen in Table 4.4, the t-test rejects the null hypothesis that the average production growth under inflation is equal to that under deflation, thereby confirming the finding. In contrast, the standard deviations of growth rates are similar, which is also supported by the testing of equality of variances.

We performed the same analysis also for real gross value added (see Table 4.3). Here the better performance under deflation is even more pronounced: 77.8% of deflationary observations report positive growth in gross value added, while for inflationary observations the percentage is only 52.3%. The average growth of gross value added is 14.1% with deflation, while only 0.68% with inflation. The difference is also confirmed by the t-test. The only difference with gross value added as opposed to production is the higher standard deviation with deflation than with inflation.

The reason for these findings may be the prevalence of supply-driven sector deflation in our sample: the sectors that reported product price deflation could be precisely the ones that invested most in production and therefore enabled cheaper and greater production.

In Section 4.A of the Appendix to this chapter, we reverse our perspective and ask the question how much growth in prices there is under the opposite scenarios of rise and fall in production and GVA. This complements our result here that sector deflation is accompanied by quicker output growth.

To check whether these results are more general or unique to the Czech Republic, we performed the same analysis on data from Japan and the United States. Interestingly, Japan shows a very similar picture (Tables 4.5 and 4.6 and Figure 4.5). Sectors undergoing output price deflation show production growth more frequently than sectors undergoing output price inflation. Mean growth of output is higher in deflating sectors than in inflating sectors, where mean growth is even negative. The difference is also confirmed by statistical tests. We find these results rather surprising given the reputation of Japan as a country with a notorious deflation problem.

Results for the US give a more mixed picture depending on the sample used. Since the results for the US take more space, we include them in Appendix 4.B to this chapter. The 1999–2015 sample shows that deflating sectors had considerably worse output growth than those with rising prices (0.45% vs. 1.81%). Interestingly, this was not mirrored in the GVA where deflating sectors performed better. This suggests that there were sectors where firms managed to cut costs meaningfully in an environment of decreasing prices. The very long 1948–2017 sample, in contrast, shows a much more balanced performance of inflating versus deflating sectors. Mean growth of production is somewhat higher under sector deflation (2.75% vs. 2.38%), but the difference is not of statistical significance. GVA shows again much higher growth under sector deflation.

Figure 4.3: Production and GVA growth against change of prices: Czech Republic 1994–2015

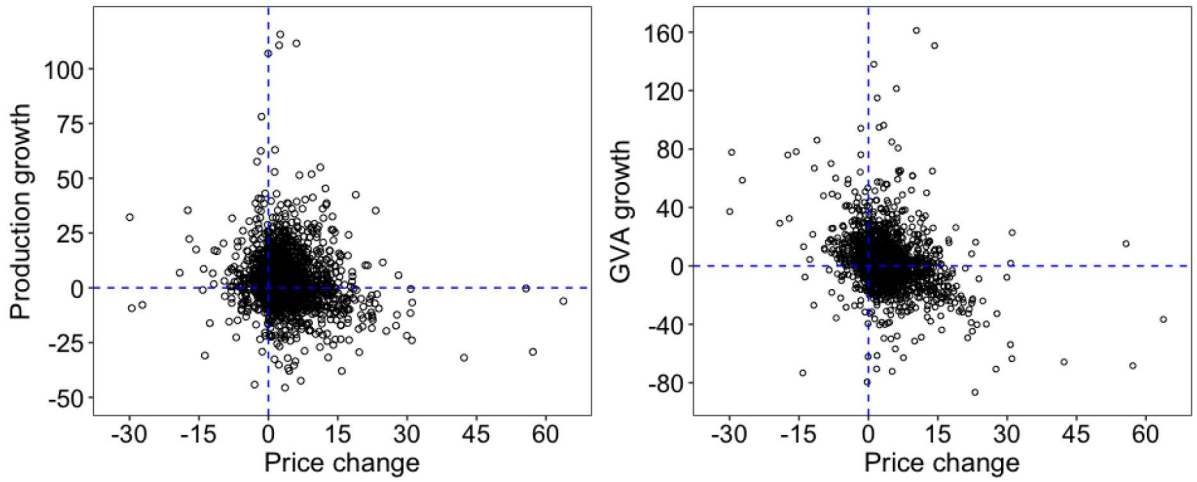


Table 4.3: Growth of production and GVA under inflation and deflation: Czech Republic 1994–2015

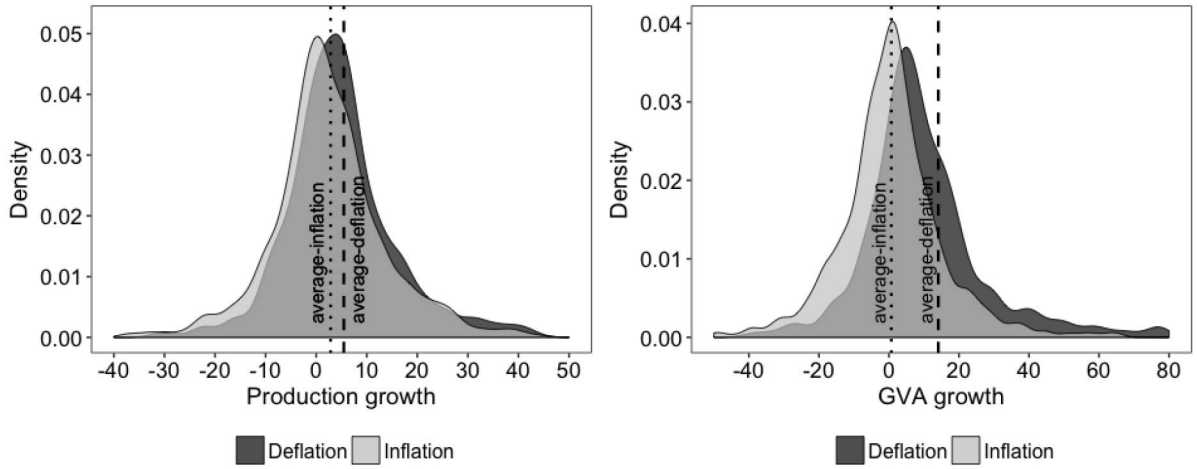
	All data	Sector inflation	Sector deflation
Observations	1892	1509	383
Production			
∼ obs. with production increase	61.0%	58.8%	69.7%
∼ obs. with production decrease	39.0%	41.2%	30.3%
Mean growth	3.38	2.85	5.47
Standard deviation of growth	12.89	12.71	13.39
Gross value added			
∼ obs. with GVA increase	57.5%	52.3%	77.8%
∼ obs. with GVA decrease	42.5%	47.7%	22.2%
Mean growth	3.40	0.68	14.1
Standard deviation of growth	34.86	25.74	57.05

Table 4.4: Tests of equality of means and variances: Czech Republic 1994–2015

	Test statistic	p-value
Production growth		
t-test for equality of means	3.44***	< 0.001
F-test for equality of variances	1.11	0.190
Gross value added growth		
t-test for equality of means	4.49***	< 0.001
F-test for equality of variances	4.91***	< 0.001

Null hypothesis: Means (variances) are equal under inflation and deflation.
Welch unpaired and two-sided t-test used for means, F-test used for variances.
* denotes statistical significance at 10%, ** at 5% and *** at 1% level.

Figure 4.4: Density of production and GVA growth under deflation and inflation: Czech Republic 1994–2015



The difference between the 1999–2015 and the 1948–2017 sample for the United States may be due to the composition of data used. The long 1948–2017 sample has 40 sectors, out of which 26 sectors are goods-producing and 14 sectors service-providing. In contrast, the newer and shorter 1999–2015 sample has 63 sectors, out of which 26 sectors are goods-producing and 37 service-providing. If many observations of deflation are due to productivity-driven, supply-side deflation, then these are much more likely to come from the production of goods. For example, in all countries covered, the most deflating sector is the production of computers, electronics and optics, where productivity improvements are strong. The growing importance of services has led to their higher share in the national accounts statistics, which means that productivity-driven deflation becomes less frequent relative to demand-driven deflation that is more likely for services. This consideration may also explain why the modern sample for Japan differs so much from the modern sample for the US. In Japan, there are 29 sectors reported with 18 of them representing production of goods. This is the opposite to the US where a large majority of reported sectors is now occupied by services. However, this pattern does not fit the Czech data: although a minority of sectors (34 out of 86) represents goods production, our data shows much better production performance under deflation. Mean growth of production under inflation and deflation for the three countries is summarized in Figure 4.6.

Table 4.5: Growth of production under inflation and deflation: Japan 1995–2015

	All data	Sector inflation	Sector deflation
Observations	609	269	340
Production			
∼ obs. with production increase	56.7%	49.8%	62.1%
∼ obs. with production decrease	43.3%	50.2%	37.9%
Mean growth	0.27	-0.42	0.82
Standard deviation of growth	5.65	3.98	6.64

Table 4.6: Tests of equality of means and variances: Japan 1995–2015

	Test statistic	p-value
Production growth		
t-test for equality of means	2.87***	0.004
F-test for equality of variances	2.79***	< 0.001

Null hypothesis: Means (variances) are equal under inflation and deflation.
Welch unpaired and two-sided t-test used for means, F-test used for variances.
* denotes statistical significance at 10%, ** at 5% and *** at 1% level.

Figure 4.5: Density of production growth under deflation and inflation: Japan 1995–2015

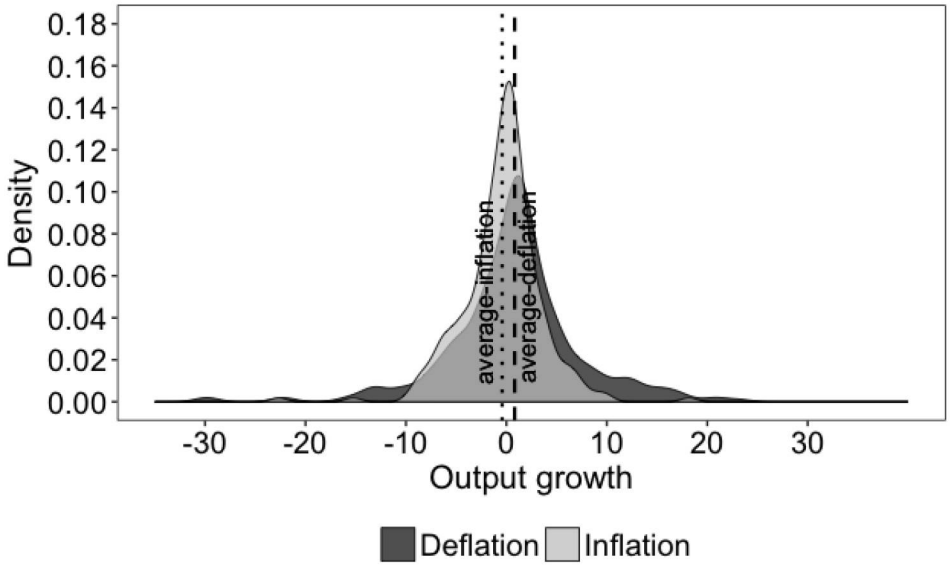
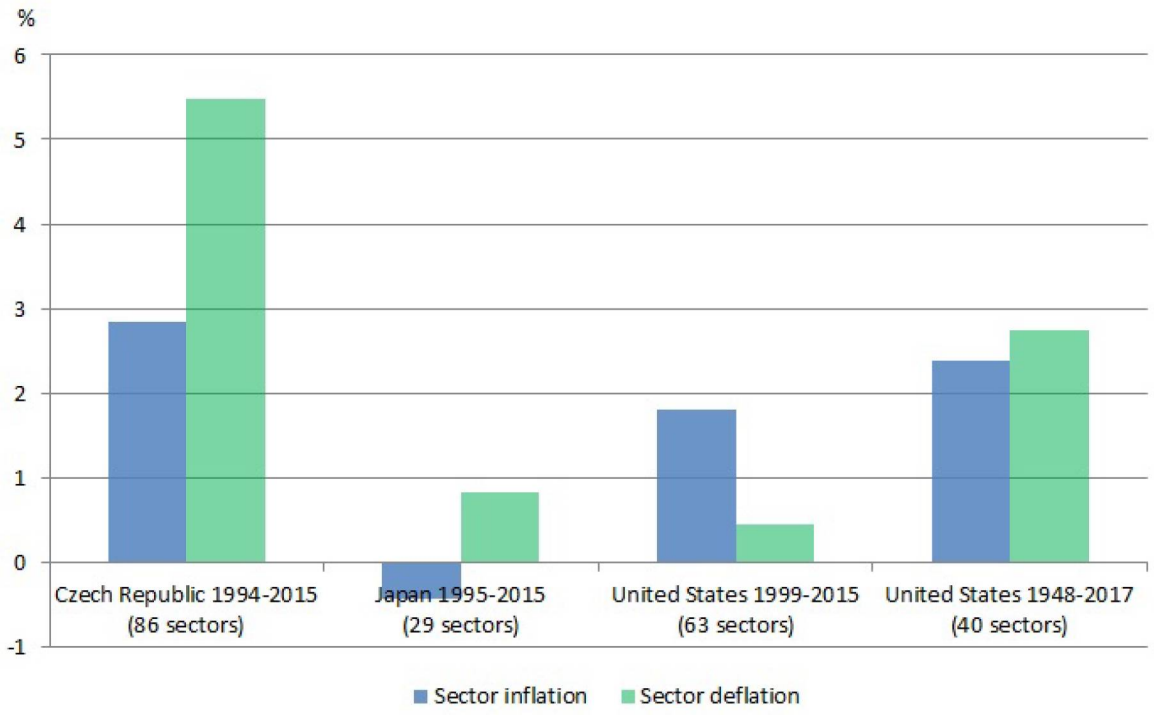


Figure 4.6: Growth of production in sectors under inflation and deflation: averages for Czech Republic, Japan and United States



Values are arithmetic averages of growth rates of production over sectors and years in the given economy, with observations assorted according to sector inflation vs. deflation. Observations: Czech Republic 1994–2015: 1892; Japan 1995–2015: 609; United States 1999–2015: 1071; United States 1948–2017: 2800.

4.5 Long-run Observations for Output and Prices

We first take a look at time averages of price growth and real output growth to get an idea of potential links at hand. We averaged observations over time for each sector, obtaining the average growth rate of real output and the average growth rate of prices for each sector in each country. This has two advantages, one theoretical and one practical. First, it captures the multi-year average trends in output and prices. For example, a sustained fall in prices in a certain sector could point to continuous investment and productivity improvements. Second, as there are hundreds to thousands of observations for each country, averaging over time helps simplify the visualization of how most sectors do in terms of output and prices. Our approach here mirrors the one that Barro (1995) and MaCandless and Weber (1995) used for a panel of countries: they computed average growth rates of output and prices for each country and used least-squares regressions or simple correlations to capture their relationships. Here, we use sectors instead to obtain the time averages, and we replicate the method for all three countries involved. Besides overall results, we also split each country's sample into years of economic growth and years of recession, based on aggregate real GDP growth. Of course, since we only run a simple regression, we do not assert that we explain causalities. Rather, we want to get a

preliminary idea about the shape of the relationship.[41]

The results of these simple regressions are reported in Tables 4.7 and 4.8. We also visualize the results for the Czech Republic in Figure 4.7.[42] There are two important observations.

First, using all years, there is a fairly repeated pattern of sector inflation being negatively and statistically significantly correlated to sector output growth and to GVA growth.[43] This holds when we single out the low-inflationary period 2001–2015 from the Czech sample 1994–2015 and it also holds for Japan and three samples for the United States, which differ by length and the number of sectors. In the top-left chart in Figure 4.7, we point out the two sectors with the lowest average sector inflation in the Czech Republic. The only sector cumulatively deflating over 1994–2015 is the production of computers, electronics and optics and that is also the highest growing sector. The second lowest sector inflation was recorded by automobile production.

Second, when we split the years between boom years and recession years and compute averages separately, the latter show repeatedly smaller coefficient estimates in absolute value and weaker statistical significance. This could suggest that if there is a relationship between sector output growth and sector inflation, it may be different in and outside recessions. This could in turn reflect different sources of sector inflation or deflation in times of growth and times of recession: if output growth is stronger in deflationary or low-inflationary sectors in times of growth, it could represent supply-driven deflation stemming from productivity improvements; on the contrary, the weaker link between output growth and price growth during recessions may indicate that demand-driven deflation appears in recessions which does not appear in times of growth.[44] Remarkably, the weaker link in recessions does not repeat itself with GVA. Here, even in recessions, sectors with deflation or low inflation tend to have higher GVA growth. This suggests that sectors with deflation or low inflation have a superior capacity to align input prices with output prices. This is certain in cases where deflation is only productivity-driven (in boom times), but as the data suggest the adjustment also appears in some cases where deflation is passively accepted by the firm, so that it has to adjust its costs side (during a slowdown of demand).

Overall, these results show an interesting correlation which could point to a prevalence of supply-driven deflation and relatively low incidence of demand-driven deflation. The cross-section regressions do not prove or refute either type of deflation, but give an idea about their relative appearance in the samples. However, we do not overestimate these results given that they lacked control variables. We exploit the data more in a panel setting below.

[41] A similar method is practiced by Atkeson and Kehoe (2004) and Benhabib and Spiegel (2009), who use 5-year averages and simple correlations without control variables.

[42] As we single out recession and non-recession years from the sample, the two smaller subsets produce a higher variation of the computed time averages. As a result, there appear several outliers that may—given the relatively low number of observations—substantially affect the coefficient estimates. To account for this, we leave out observations where any variable (output growth, GVA growth, price growth) is outside the [-20%, +20%] interval. The thresholds are the same as in macroeconomic analysis in Chapter 3. We also tried leaving out further outlying observations, but the negative and statistically significant coefficients remained.

[43] For Japan, we do not have data on GVA, so it is left out in Table 4.8.

[44] One could also think of increased competition (or reduced monopoly power) as a source of deflation or lower inflation in a sector. It can be linked to better productivity (lower costs) as this attracts new market participants. However, reduced monopoly power can also take place independently of productivity and costs.

Table 4.7: Cross-section regression of time averages: Regressions of output growth on price growth

	Coeff. est. on $\mathsf{p}^{\mathsf{avrg}}$	p-value	Observations (sectors)	*Adj.* R^2
		Czech Republic 1994–2015		
All years	-1.118^{***}	< 0.001	86	0.227
Outside recessions	-0.868^{***}	< 0.001	85	0.181
Recessions	-0.451^{*}	0.053	86	0.045
		Czech Republic 2001–2015		
All years	-1.066^{***}	< 0.001	86	0.178
Outside recessions	-0.956^{***}	< 0.001	84	0.189
Recessions	0.021	0.927	86	-0.012
		Japan 1995–2015		
All years	-0.768^{***}	< 0.001	29	0.333
Outside recessions	-0.800^{***}	< 0.001	29	0.321
Recessions	-0.067	0.869	29	-0.036
		United States Sample A 1999–2015		
All years	-0.233	0.149	63	0.018
Outside recessions	-0.265^{*}	0.050	63	0.046
Recessions	-0.346	0.257	62	0.005
		United States Sample B 1948–2017		
All years	-0.485	0.270	40	0.118
Outside recessions	-0.726^{*}	0.074	40	0.197
Recessions	-0.049	0.828	40	-0.025
		United States Sample C 1964–2017		
All years	-0.552^{**}	0.018	65	0.107
Outside recessions	-0.687^{***}	< 0.001	65	0.172
Recessions	-0.129	0.517	65	-0.009

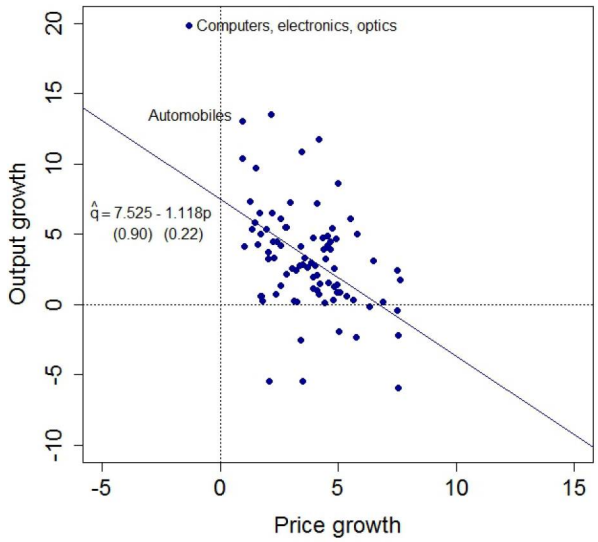
Model: $\mathsf{q}_\mathsf{i}^{\mathsf{avrg}} = \beta_0 + \beta_1 \mathsf{p}_\mathsf{i}^{\mathsf{avrg}} + \epsilon_i$, where i signifies sector. Estimated by OLS. In case heteroscedasticity detected, White's heteroscedasticity-corrected covariance matrix used. Outliers where any variable (output growth, GVA growth, price growth) is outside the (-20%, +20%) interval were left out. Software: R.

Table 4.8: Cross-section regression of time averages: Regressions of GVA growth on price growth

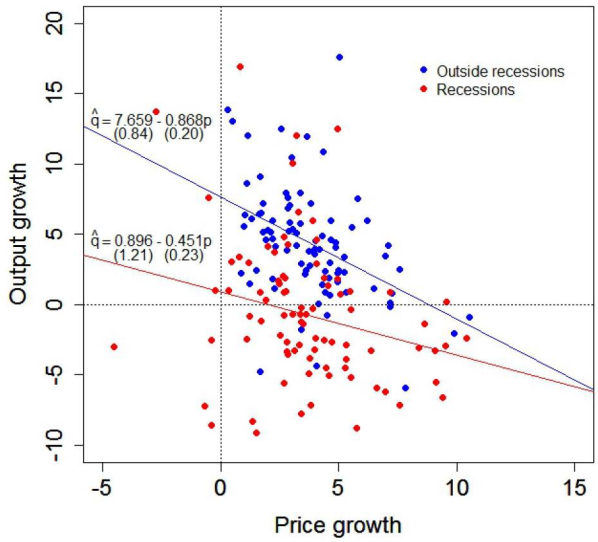
	Coeff. est. on $\mathsf{p}^{\mathsf{avrg}}$	p-value	Observations (sectors)	*Adj.* R^2
		Czech Republic 1994–2015		
All years	-1.518^{***}	< 0.001	84	0.231
Outside recessions	-1.642^{***}	< 0.001	84	0.394
Recessions	-1.243^{***}	< 0.001	80	0.227
		Czech Republic 2001–2015		
All years	-1.196^{**}	0.027	86	0.046
Outside recessions	-1.733^{***}	< 0.001	83	0.367
Recessions	-0.731^{**}	0.044	81	0.078
		United States Sample A 1999–2015		
All years	-0.518^{**}	0.019	63	0.073
Outside recessions	-0.473^{**}	0.014	63	0.080
Recessions	-1.244^{***}	0.001	61	0.204
		United States Sample B 1948–2017		
All years	-0.537	0.105	40	0.043
Outside recessions	-0.936^{**}	0.024	40	0.104
Recessions	-0.642^{**}	0.034	40	0.090
		United States Sample C 1964–2017		
All years	-0.811^{***}	0.002	65	0.130
Outside recessions	-1.028^{***}	< 0.001	65	0.190
Recessions	-0.637^{***}	0.001	64	0.141

Model: $\mathsf{gva}_\mathsf{i}^{\mathsf{avrg}} = \beta_0 + \beta_1 \mathsf{p}_\mathsf{i}^{\mathsf{avrg}} + \epsilon_i$, where i signifies sector. Estimated by OLS. In case heteroscedasticity detected, White's heteroscedasticity-corrected covariance matrix used. Outliers where any variable (output growth, GVA growth, price growth) is outside the (-20%, +20%) interval were left out. Software: R.

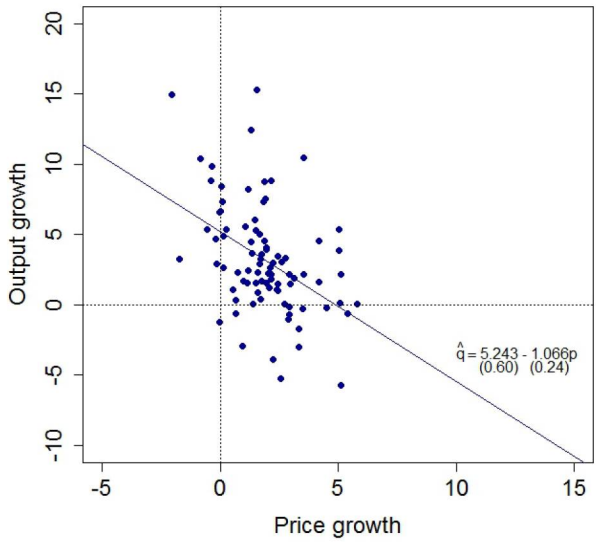
Figure 4.7: Sector growth rate of output and prices in Czech Republic 1994–2015: Averages for all years, years of recession and years outside recessions



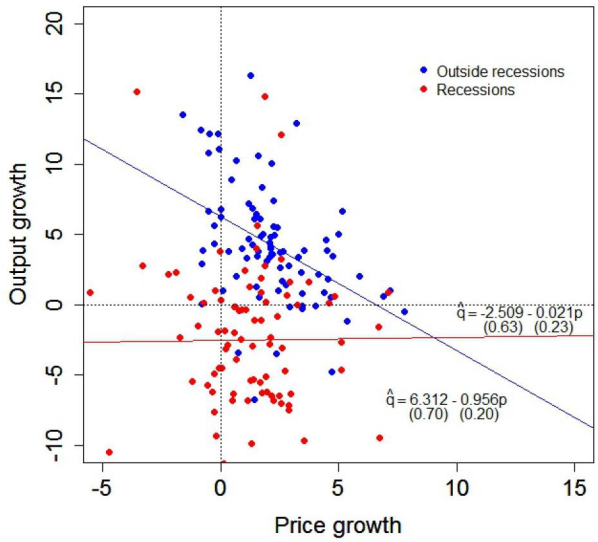
(a) 1994–2015: All years



(b) 1994–2015: In and outside recessions



(c) 2001–2015: All years



(d) 2001–2015: In and outside recessions

Note: Points represent sectors of the economy. Price growth and output growth are arithmetic averages over all years (panels (a) and (c)) or averages over years of recessions and years outside recessions (panels (b) and (d)). Sectors: 86. Years of recession: 1997, 1998, 2009, 2012, 2013. Numbers in parentheses denote standard errors.

4.6 Panel Data

4.6.1 Model and Dealing with Endogeneity

The panel data setting allows us to look at the relationship between output growth and sector inflation across various economic sectors and time. Our goal is similar to that on the macroeconomic level: to find out whether output growth is affected by price growth after controlling for demand and supply factors where possible. However, since we are now dealing with the determination of output (quantities) and prices *within* a given sector over time, we have to assume separate supply and demand processes at work. In the simplest form, we can write them as

$$\mathsf{Q}^{\mathsf{S}}_{\mathsf{it}} = \alpha_0 + \alpha_1 \mathsf{P}_{\mathsf{it}} + \epsilon_{it}$$

$$\mathsf{Q}^{\mathsf{D}}_{\mathsf{it}} = \beta_0 + \beta_1 \mathsf{P}_{\mathsf{it}} + u_{it}$$

We are most interested in the demand equation since this equation can inform us about the potential reaction of consumers and firms to the development in prices. (We are now for starters showing a static model but will move to one with growth rates below.) This is our sector equivalent to the macroeconomic question whether consumers and firms reduce spending in reaction to a certain development in prices. We point out that our sectors do not only contain those that produce final-consumption goods, but also those that produce capital goods and inputs for other firms. Therefore, the demand equation above is not only that of consumers, but more generally a demand equation of consumers and firms.

Every observation in our data set is one of equilibrium price P_{it} and equilibrium quantity $\mathsf{Q}^{\mathsf{S}}_{\mathsf{it}} = \mathsf{Q}^{\mathsf{D}}_{\mathsf{it}} \equiv \mathsf{Q}_{\mathsf{it}}$, so that demand and supply equations in this form cannot be discerned from each other. In other words, if we attempt to estimate the demand equation above as it is, we run the risk of endogeneity. Price is assumed to affect quantity, but quantity produced simultaneously affects the market price. Price P_{it} in the demand equation is correlated with the error term u_{it}, which renders the coefficient estimates biased.

We address this issue by choosing an instrumental variable for P_{it} in the demand equation. This variable should satisfy both the inclusion restriction that it is correlated with P_{it} and the exclusion restriction that it may be linked with output Q_{it} only indirectly through P_{it} but not directly correlated. The national accounts data offer several variables for inputs in production. For instance, in the case of the Czech Republic, there are data on intermediate inputs and their prices and also on employed hours worked and employee compensation. We have tested for the satisfaction of inclusion and exclusion restrictions in each specification below, but as a general rule, the prices of intermediate inputs satisfy best both restrictions. This is why in most cases we use it as instrument for P_{it}. The need for an instrumental variable is not only an econometric necessity, but is also in line with theory and with our knowledge from the long-run averages. If the shape of the relationship suggests long-run supply-side deflation playing a role, it should be accounted for in a more detailed regression.

Finally, in a parallel to the macroeconomic approach, we also want to control for demand factors. Since we have both consumers and firms as the purchasers of the produced output,

we use the money supply or the combined consumer and business credit in the economy as a demand shifter. Thus, our demand equation in a form with growth rates is

$$\mathsf{q}_{\mathsf{it}}^{\mathsf{D}} = \beta_0 + \beta_1 \widehat{\mathsf{p}_{\mathsf{it}}} + \beta_2 \mathbf{X}_{\mathsf{t}} + u_{it}$$

where q_{it} is the growth rate of real output (percent annual change), p_{it} is the growth rate of output prices (the hat sign denotes that it is instrumented in most specifications below) and $\mathbf{X}_{\mathsf{t}}$ is a vector of control variables again in growth rates. Here, we include the growth rate of combined consumer and business credit ($\mathsf{credit}_{\mathsf{t}}$), growth in money supply M2 ($\mathsf{money}_{\mathsf{t}}$) and we also use a recession dummy variable ($\mathsf{recession}_{\mathsf{t}}$), which takes the value of 1 when the economy was in a recession (according to annual change in real GDP) and 0 when it was not. We include the recession dummy since the long-run averages in the previous section indicated that the relationship between sector output growth and sector inflation might be different in a recessionary environment and in times of growth.[45] We do not use lagged variables since the model is essentially one of microeconomic choice where demand for goods and services is assumed to be driven by contemporaneous prices and other variables.

4.6.2 Results

Baseline Sample

We are most interested in the sign and significance of the coefficient estimate for price growth for the main Czech sample 1994–2015. As expected by the theory above, tests indicate that p_{it} is endogeneous in the demand equation above.[46]

For 2SLS and GMM, our choice of instrument is the price growth of intermediate inputs in production $\mathsf{p}_{\mathsf{it}}^{\mathsf{input}}$ which captures an important part of costs of production. This variable has a positive and significant correlation with p_{it} but very small correlation with q_{it}.[47]

We are aware that it would be optimal to have more than one satisfactory instrument so that exogeneous instruments could be weighted optimally. Since more instruments are not available in most specifications below and $\mathsf{p}_{\mathsf{it}}^{\mathsf{input}}$ could be a weak instrument, we estimate the demand equation first without and then with instrumentation, so that results could be compared.

Table 4.9 shows estimates of coefficients for 8 different specifications together with p-values in brackets. We use three different estimation methods: panel fixed effects, panel two-staged

[45] The inclusion of the recession dummy might look tautological since the dependent variable is the change in real sector output—hence, the relationship would say that when there is a recession, output falls, which is true by definition. However, the recession dummy is constructed based on change in aggregate real GDP, not sector output. Further, sector output includes exports of goods and these are likely to be more dependent on foreign economic cycles than the domestic ones, and these may be different. This was, for example, the case of the 1997-98 Czech recession. Below we try specifications with and without this dummy to check the results. We thank Jaromír Baxa for pointing out the risk with the recession dummy.

[46] We have tested for endogeneity of p_{it} by regressing it on all other regressors in the above demand equation plus price growth of intermediate inputs $\mathsf{p}_{\mathsf{it}}^{\mathsf{input}}$. We then estimated the demand equation with residuals of p_{it} that resulted from the first regression. The significant coefficients on these residuals point to endogeneity. This was also confirmed by software-provided Hausman tests.

[47] For example, in the sample for Czech Republic in 1994–2015, $\mathsf{p}_{\mathsf{it}}^{\mathsf{input}}$ has a correlation coefficient with q_{it} of -0.01 and insignificant on any standard significance level. Other considered instruments had positive and significant correlations with q_{it}, which would violate the exclusion restriction. The correlation coefficient between $\mathsf{p}_{\mathsf{it}}^{\mathsf{input}}$ and p_{it} is 0.55 and stat. significant.

least squares (2SLS) with fixed effects and panel two-step generalized method of moments (GMM).

In the first sample (Czech Republic 1994–2015), the coefficient estimate for p_{it} is negative throughout the specifications. First, in the panel fixed effects model, we start with only prices and gradually add regressors. Money supply (M2) growth turns out to have greater effect on output growth (and add more to R^2) than credit growth, which is why we keep money in the regression for the further specifications. As the table shows, the coefficient estimate for p_{it} somewhat changes as we add regressors, but stays negative and statistically significant for the panel fixed effects model. Interestingly, the addition of the recession dummy, which could capture a change in the link of output growth and price growth as the economy moves in and out of recessions, does not change the results materially. Second, we run 2SLS and GMM with price growth of intermediate inputs as an exogenous instrument for prices. GMM uses, on top of this exogenous instrument, also lags of 2 to 5 of the endogenous variable p_{it}. Under the 2SLS and GMM setting, the coefficient loses some magnitude but stays negative. While it loses statistical significance under 2SLS, it remains significant under GMM. The F-statistic of the first-stage regression in 2SLS was 8.8, which casts some doubt on the instrument.[48] This leads us to caution when interpreting the results of instrumentation. Otherwise, all the other coefficient estimates have the expected signs: money and credit affect sector output positively throughout the specifications, while the recession dummy has a sharply negative effect. The R^2's are rather low, but this is not surprising given that the panel regression estimates effect on *sector* output growth using only two variables which are also sector-specific (prices and input prices), while the other variables capture the whole economy and change only in time.

Sensitivity Analysis

We have performed a number of sensitivity checks to see whether the negative coefficient estimate for p_{it} is rather unique to the main sample analyzed or whether it is a more general regularity. First, we performed the same regression on a shorter Czech sample 2001–2015 (bottom part of Table 4.9). The coefficient estimate for p_{it} is very similar for the panel fixed effects without instrumentation. In 2SLS, it rises to positive values, yet these are insignificant, while in GMM, it stays negative and statistically significant. It is necessary to add, however, that the first-stage F-statistic is low in 2SLS (2.5), which raises doubt about the reliability of the instrument. Overall, it does not seem that the transition of the Czech economy to the low-inflationary post-2000 period had a large impact on the link between sector inflation and output growth.

Second, we divide the sectors between those producing goods and those providing services. Out of the 86 sectors of the Czech economy, the split is 34 goods-producing to 52 service-providing sectors. The idea behind this division comes from theory. If consumers and firms postpone purchases due to deflating prices, there could be reasons why this should impact goods more than services. For example, a consumer is more likely to postpone the purchase of a new car or a new TV set rather than postpone a phone call or the service of a hairdresser. Similarly, a firm may put off buying new capital goods or having its offices refurbished, but it

[48] For example, the Gretl software states that a first-stage F-statistic lower than 10 generally suggests the 2SLS instrument could be weak.

cannot put off paying its accountant. There is also a second reason to explore these two areas. The goods sector in the Czech Republic both imports and exports heavily, which is why the recorded sector inflation in these sectors could be lower due to long-run appreciation of the Czech koruna to the euro and the US dollar. Goods production could also be subject to much higher productivity gains, which is another reason of a tendency to have lower prices.

In Table 4.10, we report separately the results for goods-producing and service-providing sectors. Overall, the picture stays much the same: negative and statistically significant coefficient estimates for p_{it} prevail in both cases. In addition, however, in the services case even the 2SLS estimates become highly statistically significant and also grow in absolute value. Interestingly, the instrumental variable seems to work better in the services case as the first-stage F-statistic grows to 12.1 in the services sample from 6 in the goods sample. It is difficult to judge whether this difference in the goods and services is due to the workings of the instrument or whether it captures a true difference in behaviour of economic agents towards goods versus services. What seems clear, however, is that even in the goods case we do not find evidence that consumers and firms would cut back on purchases in light of sector deflation or slowing inflation, having controlled for demand and supply factors.

Finally, in Table 4.11, we report results for Japan in 1995–2015 and for the United States in 1999-2015. We have chosen these modern samples so that they are comparable to the Czech Republic. In both countries, credit has a bigger effect on output growth as compared to money supply, which is why we use it in most specifications. Overall, it seems that the link between price growth and output growth is weaker both in terms of absolute magnitude and statistical significance. This is clear especially in the US, where the coefficient estimate p_{it} is mostly slightly positive but insignificant. This is in line with our observations from Sections 4.4 and 4.5 that the modern US sample probably shows relatively more demand-driven than supply-driven sector deflations. Thus, if there are demand factors that are not controlled for by our control variables credit and money, these could weigh more on the results and explain the difference of the US compared to the Czech Republic and Japan. In contrast, Japan resembles more the Czech Republic as the coefficient estimates are mostly negative and sometimes significant. This could be of interest. Japan is the one country that has spent the whole period covered (1995-2015) with the zero-lower bound binding and with repeated aggregate deflation. Yet, the present panel data show no indication that consumers and firms would react to falling prices by cutting purchases.

We have also performed other sensitivity tests that we do not report here numerically. We used time dummies, we cast the problem as one of three-stage least squares, we have removed outliers and we left out commodities sectors which have relatively volatile price changes. We have also performed the split to goods an services on Japan and US and we have investigated also the longer samples for the United states (1948–2018 and 1964–2017). None of these checks materially changed the results.

Table 4.9: Effect of sector price growth on output growth: Czech Republic

	Panel Fixed Effects				2SLS FE		GMM	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Czech Republic 1994–2015				
constant	4.34***	0.59	3.58***	2.14***	0.36	2.10***	–	–
	[0.00]	[0.29]	[0.00]	[0.00]	[0.53]	[0.00]	–	–
p_{it}	−0.26***	−0.42***	−0.28***	−0.39***	−0.12	−0.10	−0.17***	−0.15***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.51]	[0.57]	[0.00]	[0.00]
$money_t$	–	0.53***	–	0.44***	0.41***	0.31***	0.41***	0.31***
	–	[0.00]	–	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$credit_t$	–	–	0.13***	–	–	–	–	–
	–	–	[0.00]	–	–	–	–	–
$recession_t$	–	–	–	−3.91***	–	−4.39***	–	−3.49***
	–	–	–	[0.00]	–	[0.00]	–	[0.00]
Observations	1892	1892	1892	1892	1870	1870	1785	1785
R^2	0.11	0.15	0.12	0.17	0.13	0.15	-	-
				Czech Republic 2001–2015				
constant	3.77***	−2.26***	2.97***	0.48	−3.64**	−1.00	–	–
	[0.00]	[0.00]	[0.00]	[0.61]	[0.01]	[0.51]	–	–
p_{it}	−0.28***	−0.33***	−0.32***	−0.37***	0.69	0.50	−0.06*	−0.19***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.40]	[0.50]	[0.08]	[0.00]
$money_t$	–	0.93***	–	0.70***	0.83***	0.64***	0.93***	0.70***
	–	[0.00]	–	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$credit_t$	–	–	0.12***	–	–	–	–	−4.99***
	–	–	[0.00]	–	–	–	–	[0.00]
$recession_t$	–	–	–	−5.83***	–	−5.21***	–	–
	–	–	–	[0.00]	–	[0.00]	–	–
Observations	1290	1290	1290	1290	1275	1275	1190	1190
R^2	0.12	0.18	0.14	0.22	0.02	0.10	-	-

Note: Dependent variable: sector output growth. All variables except recession are percent annual growth rates. Panel fixed effects and 2SLS estimated with sector dummies. GMM: Orthogonal deviation transformation subtracts the constant; two-step estimation; White period weighting matrix. Exogenous instrumental variable in 2SLS and GMM: growth rate of prices of intermediate inputs in production. Numbers in brackets are p-values based on White's heteroscedasticity and autocorrelation-corrected standard errors. Software: EViews.

Table 4.10: Effect of sector price growth on output growth: Czech Republic: Goods and services

	Panel Fixed Effects				2SLS FE		GMM	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Czech Republic 1994–2015: Goods				
constant	3.78***	−0.16	3.12***	1.68**	−0.63	1.30	–	–
	[0.00]	[0.84]	[0.00]	[0.05]	[0.46]	[0.16]	–	–
p_{it}	−0.22***	−0.29***	−0.23***	−0.28***	0.37	0.34	−0.18***	−0.18***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.35]	[0.36]	[0.00]	[0.00]
$money_t$	–	0.51***	–	0.41***	0.34**	0.24*	0.48***	0.44***
	–	[0.00]	–	[0.00]	[0.01]	[0.08]	[0.00]	[0.00]
$credit_t$	–	–	0.11***	–	–	–	–	–
	–	–	[0.00]	–	–	–	–	–
$recession_t$	–	–	–	−4.62***	–	−4.78***	–	−1.98***
	–	–	–	[0.00]	–	[0.00]	–	[0.00]
Observations	748	748	748	748	748	748	714	714
R^2	0.17	0.22	0.18	0.24	0.08	0.18	-	-
				Czech Republic 1994–2015: Services				
constant	4.86***	1.16	4.07***	2.38**	1.24	2.39***	–	–
	[0.00]	[0.13]	[0.00]	[0.01]	[0.11]	[0.01]	–	–
p_{it}	−0.31***	−0.62***	−0.35***	−0.57***	−0.83***	−0.78***	−0.42***	−0.31***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$money_t$	–	0.62***	–	0.53***	0.70***	0.61***	0.51***	0.35***
	–	[0.00]	–	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$credit_t$	–	–	0.15***	–	–	–	–	−4.12***
	–	–	[0.00]	–	–	–	–	[0.00]
$recession_t$	–	–	–	−3.13***	–	−2.96***	–	
	–	–	–	[0.00]	–	[0.00]	–	
Observations	1144	1144	1144	1144	1122	1122	1071	1071
R^2	0.08	0.13	0.09	0.13	0.12	0.13	-	-

Note: Dependent variable: sector output growth. All variables except recession are percent annual growth rates. Panel fixed effects and 2SLS estimated with sector dummies. GMM: Orthogonal deviation transformation subtracts the constant; two-step estimation; White period weighting matrix. Exogenous instrumental variable in 2SLS and GMM: growth rate of prices of intermediate inputs in production. Numbers in brackets are p-values based on White's heteroscedasticity and autocorrelation-corrected standard errors. Software: EViews.

Table 4.11: Effect of sector price growth on output growth: Japan and United States

	Panel Fixed Effects				2SLS FE		GMM	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Japan 1995–2015				
constant	0.26	2.11***	0.80***	1.54***	0.68***	1.41***	–	–
	[0.21]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	–	–
p_{it}	−0.06	−0.07	−0.12	−0.17*	0.15	0.07	−0.15***	−0.17***
	[0.54]	[0.48]	[0.19]	[0.071]	[0.33]	[0.59]	[0.00]	[0.00]
$money_t$	–	−0.69***	–	–	–	–	–	–
	–	[0.000]	–	–	–	–	–	–
$credit_t$	–	–	0.42***	0.24***	0.30***	0.14	0.23***	0.17***
	–	–	[0.00]	[0.01]	[0.01]	[0.17]	[0.00]	[0.00]
$recession_t$	–	–	–	−4.13***	–	−3.97***	–	−4.26***
	–	–	–	[0.00]	–	[0.00]	–	[0.00]
Observations	609	609	609	609	609	609	580	580
R^2	0.19	0.20	0.21	0.30	0.18	0.28	-	-
				United States 1999–2015				
constant	1.35***	7.32***	−1.02**	0.68*	−1.11***	0.57	–	–
	[0.00]	[0.00]	[0.01]	[0.08]	[0.00]	[0.10]	–	–
p_{it}	0.10**	0.06	0.01	0.02	0.09	0.13	−0.02***	0.01***
	[0.02]	[0.17]	[0.74]	[0.60]	[0.28]	[0.18]	[0.00]	[0.00]
$money_t$	–	−0.91***	–	–	–	–	–	–
	–	[0.00]	–	–	–	–	–	–
$credit_t$	–	–	0.51***	0.30***	0.50***	0.27***	0.60***	0.30***
	–	–	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$recession_t$	–	–	–	−5.35***	–	−5.42***	–	−5.89***
	–	–	–	[0.00]	–	[0.00]	–	[0.00]
Observations	1071	1071	1071	1071	1071	1071	1008	1008
R^2	0.12	0.16	0.24	0.28	0.23	0.27	-	-

Note: Dependent variable: sector output growth. All variables except recession are percent annual growth rates. Panel fixed effects and 2SLS estimated with sector dummies. GMM: Orthogonal deviation transformation subtracts the constant; two-step estimation; White period weighting matrix. Exogenous instrumental variable in 2SLS and GMM: growth rate of prices of intermediate inputs in production (Japan), growth rate of prices of material inputs and service inputs (US). Numbers in brackets are p-values based on White's heteroscedasticity and autocorrelation-corrected standard errors. Software: EViews.

4.7 Interpretation and Discussion

The empirical results bring, in our view, several important findings.

First, both descriptive statistics and long-run averages of sector inflation and sector growth suggest that supply-driven deflation is highly present in the samples. The long-run averages of all years and outside-recession years show that sectors with deflation or below-average inflation tend to have quicker output growth and GVA growth. In contrast, this relationship becomes weaker when considering only in-recession years. This fact could be explained by the prevalence of supply-driven deflation in our observations, because this type of deflation is dominant in outside-recession times while it competes in frequency with demand-driven deflation in recession times. The possibility to uncover the presence of observations with fast growth in output and low or negative price growth is a feature of sector data that cannot be emulated by aggregate data.

Second, gross value added appears to grow much faster under deflation than inflation and this relationship is present even in cases where output growth is not superior in deflating sectors compared to inflating sectors. This could suggest that firms do well in adjusting their costs even when output price cuts are imposed from outside and not linked to their expanding output. Inspecting the cost behaviour of firms is outside the scope of this text, but these observations suggest that it would be worthwhile in relation to the study of deflation.

Third, and most importantly, our results from panel data do not find evidence that deflation of prices would lead, on average, to cuts in demanded quantities of the respective goods, having controlled for demand and supply factors. On the contrary, the coefficient estimates on price growth—when statistically significant—tend to have a negative sign in explaining quantity demanded. We did not find a positive and statistically significant coefficients in any of the samples and specifications. If the control variables capture well the shifts of demand and supply curves, then we do not find evidence of self-perpetuating deflation where output falls together with price without needing other triggers.

There are several caveats to make. From a technical point of view, our regression analysis assumes that all sectors have equal weights, which of course is not true in terms of their share in GDP, employment, CPI and other aggregate variables. However, our analysis is theory-oriented and not designed for policy-making. If a theory is correct, it should work both for big sectors as well as small ones, so each observation is treated with equal weight.

Second, instrumenting is difficult in our setting since we have not covered only one market but a series of markets. We have used inputs prices, which are plausible as instrument both from the point of view of theory and of econometrics, but inputs prices are necessarily a better instrument for some sectors than others. For example, some service industries have very few inputs that are bought externally and measurable, while manufacturing has well-defined inputs that are in close relationship to their outputs. Therefore, if a similar analysis was performed sector by sector, it could use numerous instruments and show different results. Yet, our goal was an average response to price declines across consumers and firms.

Third, our results are valid for postponement theories of deflation and growth as long as deflation expectations can be approximated by realized contemporaneous deflation. Given that we work with annual data, we surmise that a year is a period long enough for consumers and firms to react to considerable observed inflation and deflation. In using contemporaneous annual

price growth, we mirror some macroeconomic studies such as Borio et al. (2015).

A comparison of our results with other studies is difficult for three reasons. First, no other authors, to the best of our knowledge, have used sector data to inspect the relationship between sector inflation and sector output or gross value added. Further, we have controlled for both demand and supply factors which is not the case of most studies even on the macroeconomic level. Third, our samples cover both consumer goods and capital goods, which also makes it difficult to compare with some uniquely consumer-oriented studies. We can only make comparisons in a broad sense. In this respect, our results generally confirm the results of Atkeson and Kehoe (2004), Borio and Filardo (2004) and Borio et al. (2015) who did not find evidence of a deflation-depression link in large data sets. The one feature that is somewhat similar between the sector data and the samples of these three mentioned studies is the focus on deflation-rich data. In fact, some sectors in our data set resemble the deflationary period 1866–1914 in the US and elsewhere which displayed frequent deflation with relatively high growth rates of output. Their common feature is likely to be the underlying growth in productivity which links growth in output to reductions in prices. We think that the effect of productivity improvements might be more pronounced in our study because we cover not only sectors producing for final consumption, but also sectors producing capital goods and intermediate inputs farther away in the production chain. Similarly, the results presented here are consistent with the absence of a deflation-depression link that was found in Chapter 3 of this text. Our results on the US are also in line with Bachmann, Berg and Sims (2015) who did not find evidence of postponement of consumption, but this study worked with survey of inflation expectations rather than realized inflation or deflation. In contrast, Ichiue and Nishiguchi (2014) earlier performed the same analysis on Japan and found a negative effect on deflation expectations on consumption. Needless to say, the difference between using realized data on inflation and survey answers on inflation expectations and consumption decisions may be substantial, which we discussed in Section 2.3.3.2 in the theoretical chapter. Last but not least, the studies on inflation expectations typically use much shorter samples than our panel samples which span 17 to 22 years.

4.8 Summary

This chapter has addressed a repeated and crucial problem of many macroeconomic data sets where there is a severe lack of contemporary observations of deflation. Instead of relying on pre-World War I data with frequent deflation observations, we turn to disaggregated sector data from contemporary national accounts statistics. We argue that macroeconomic theories of deflation and recession have microeconomic arguments in their core, which makes them testable on less-than-aggregate data. We also point out that there have already been pieces of literature on inflation and deflation in roughly the last decade that have argued for using narrower and more targeted price statistics. Nevertheless, we acknowledge the limitations of the sector approach and consider it a complement rather than substitute to aggregate data.

Our most important result is that after controlling for demand and supply factors, the panel data sets do not support the hypothesis that price deflation or lower inflation *on its own* leads to a drop in output growth, perhaps because of postponement of spending. Therefore, we

addressed the possibility of a 'kinked' dynamic demand curve with a different kind of data and different control variables, but with a similar answer as in the macroeconomic Chapter 3. There are several important caveats such as limited possibilities of instrumentation and reliance on contemporary realized deflation as opposed to using deflation expectations that we discussed in the previous Section 4.7. Also, we point out that the character of sector data makes the analysis useful for economic theory rather than macroeconomic policy.

An important question remains whether there is empirical evidence that some part of the deflation observed in the sector data is linked to productivity improvements. This is what we look at in Chapter 5.

Appendix

4.A Further Descriptive Statistics for the Czech Republic

In Section 4.4, we explored how much growth in production or GVA there is under inflation and deflation. To give a complete picture, we now reverse our perspective and look into how prices grow under increases versus decreases in production or GVA.

As seen in Table 4.12, the average growth of prices is significantly higher when production decreases. In addition, there are more observations of deflation when production grows (23.1%) than when production declines (15.7%).

By the same token, prices grow slower under increasing GVA than under decreasing GVA. Relatively more cases of deflation are recorded when GVA grows (27.4%) than when it falls (10.6%).

The statistical tests in Table 4.13 conclude that neither the average price changes nor variances of prices changes are equal, and that is valid for both production and GVA. In other words, the average growth of prices is significantly higher when production or GVA falls.

Finally, we visualize our findings in Figure 4.8. It is the observations with production and GVA increase that tend to have slower price growth or outright deflation.

In sum, our finding from Section 4.4 also works the other way round: not only is deflation associated with quicker output growth than inflation, but output increases are usually accompanied by lower growth of prices than output decreases.

Figure 4.8: Density of price growth under production growth and production decline: Czech Republic 1994–2015

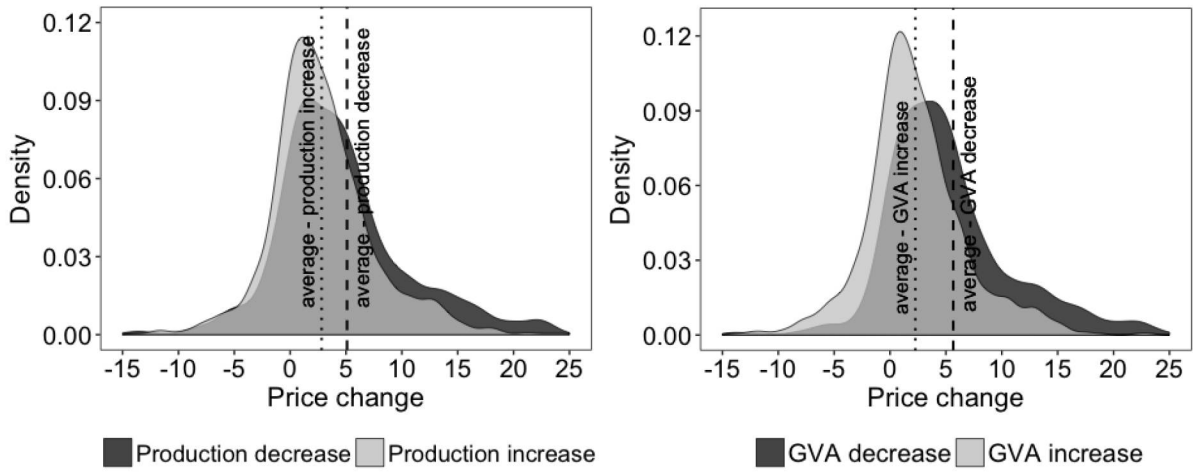


Table 4.12: Growth of prices under increase and decrease of production or GVA: Czech Republic 1994–2015

	All data	Production increase	Production decrease
Observations	1892	1154	738
Price change			
∼ obs. with price increase	79.8%	76.9%	84.3%
∼ obs. with price decrease	20.2%	23.1%	15.7%
Average price growth	3.71	2.82	5.09
Price growth st. deviation	6.14	4.88	7.51
	All data	GVA increase	GVA decrease
Observations	1892	1087	805
Price change			
∼ obs.with price increase	79.8%	72.6%	89.4%
∼ obs.with price decrease	20.2%	27.4%	10.6%
Average price growth	3.71	2.26	5.65
Price growth st. deviation	6.14	5.30	6.65

Table 4.13: Test of equality of means and variances: Czech Republic 1994–2015

	Test statistic	p-value
Price growth under production increase/decrease		
t-test for equality of means	7.30***	< 0.001
F-test for equality of variances	2.36***	< 0.001
Price growth under GVA increase/decrease		
t-test for equality of means	11.90***	< 0.001
F-test for equality of variances	1.58***	< 0.001

4.B United States 1999–2015 and 1948–2017

Below we provide descriptive statistics for two samples of the United States: 1999–2015 (63 sectors) and 1948–2017 (40 sectors).

Table 4.14: Growth of production and GVA under inflation and deflation: United States 1999–2015

	All data	Sector inflation	Sector deflation
Observations	1071	898	173
Production			
∼ obs. with production increase	68.1%	69.4%	61.3%
∼ obs. with production decrease	31.9%	30.6%	38.7%
Mean growth	1.59	1.81	0.45
Standard deviation of growth	6.74	6.15	9.16
Gross value added			
∼ obs. with GVA increase	67.4%	68.0%	70.9%
∼ obs. with GVA decrease	32.6%	32.0%	29.1%
Mean growth	2.27	1.75	4.94
Standard deviation of growth	10.25	9.69	12.46

Table 4.15: Tests of equality of means and variances: United States 1999–2015

	Test statistic	p-value
Production growth		
t-test for equality of means	1.88	0.06
F-test for equality of variances	2.22***	< 0.001
Gross value added growth		
t-test for equality of means	3.18***	< 0.001
F-test for equality of variances	1.65***	< 0.001

Null hypothesis: Means (variances) are equal under inflation and deflation.
Welch unpaired and two-sided t-test used for means, F-test used for variances.
* denotes statistical significance at 10%, ** at 5% and *** at 1% level.

Table 4.16: Growth of production and GVA under inflation and deflation: United States 1948–2017

	All data	Sector inflation	Sector deflation
Observations	2800	2366	434
Production			
∼ obs. with production increase	71.8%	72.5%	67.7%
∼ obs. with production decrease	28.2%	27.5%	32.3%
Mean growth	2.69	2.38	2.75
Standard deviation of growth	7.04	8.42	6.76
Gross value added			
∼ obs. with GVA increase	84.5%	82.7%	88.7%
∼ obs. with GVA decrease	15.5%	17.3%	11.3%
Mean growth	2.96	2.16	7.28
Standard deviation of growth	10.40	17.65	8.18

Table 4.17: Tests of equality of means and variances: United States 1948–2017

	Test statistic	p-value
Production growth		
t-test for equality of means	0.86	0.39
F-test for equality of variances	1.55***	< 0.001
Gross value added growth		
t-test for equality of means	5.93***	< 0.001
F-test for equality of variances	4.65***	< 0.001

Null hypothesis: Means (variances) are equal under inflation and deflation.
Welch unpaired and two-sided t-test used for means, F-test used for variances.
* denotes statistical significance at 10%, ** at 5% and *** at 1% level.

Chapter 5

Productivity and Deflation in Sector Data

5.1 Motivation

Supply-driven and demand-driven deflation have become accepted terms for a large part of the theoretical literature on deflation, but the supply-driven type has not inspired almost any empirical research. For example, Kumar et al. (2003) of the IMF constructed deflation indicators to assess the risks of deflation across countries. The indicators were demand-side oriented, which helped recognize the type of deflation deemed riskier, but by definition they could not capture supply-side developments. As a result, the indicators missed several years of deflation in China at the turn of the century (approx. 1998–2002), which occurred in an environment of brisk economic growth and was most probably supply-driven.

We think that there is a major gap in research on the presence and workings of supply-side, mainly productivity-driven deflation. In this chapter, we aim to partially fill this gap. Our approach is novel in terms of both data and method. We use supply-side data on 86 sectors of the Czech economy over 1993–2015 (the same years and sectors as in Chapter 4, but with more variables) to look at the link between output prices and productivity. We compute productivity scores to sort each observation of productivity relative to others, and after obtaining relative scores we regress them on price changes. We find that sector output price deflation tends to appear in sectors with the highest increases in productivity—i.e., sectors where firms have cut costs and prices thanks to more efficient production. The sectors with deflation or below-average inflation turn out to be those in rapid development, based on productivity. Our results show that the presence of sector productivity-driven deflation or below-average inflation can be demonstrated on Czech data using nonparametric methods.

This chapter is organized as follows. In Section 5.2, we discuss how the introduction of productivity may change the results of theories that study the association of deflation with recession. Section 5.3 explains our econometric method and presents our data set and variables. In particular, we lay out the construction of efficiency (productivity) scores and how we use them. We present our findings on the link between prices and productivity in Section 5.4. Section 5.5 summarizes the chapter and evaluates its implications.

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5.2 Introducing Productivity into Theory

Changes in productivity may have two different links to deflation. According to one point of view, deflation may arise as a direct manifestation of improvements in productivity. Therefore, higher growth in productivity should generally lead to a fall in prices or at least should work to slow down their growth. Second, the Balassa-Samuelson effect stipulates—if certain conditions are met—that increases in productivity in a small, open economy should lead to increases in prices in the non-tradables sectors. We discuss these theories in turn and assess how they could be interpreted in sector data.

Productivity-driven deflation

The link from productivity improvements to potential deflation is rather straightforward: investment allows reduction in costs per unit of output, which moves down the marginal cost curve and leads to a market equilibrium with lower prices. Interestingly, the arguments that link deflation with recession, listed in Chapter 2, do not stipulate where deflation must come from or what kind of deflation must appear in order to have the given link to recession. As a result, it is key to explain how productivity-driven deflation may crucially impact the deflation-recession links.

As explained in more detail in Chapter 2, there are three most common arguments against deflation. First, deflation—and the expectation that it will continue—may cause consumers to put off purchases and, by the same token, induce businesses to put off investment. Consumers may want to save money by buying cheaper in the future and businesses do not want to invest with the vision of falling prices and revenues. Second, deflation can cause problems for firms if there are nominal rigidities that make it impossible to cut input prices and wages, at least in the short run. This may squeeze profitability and cause closures of businesses. Third, unanticipated deflation may be harmful for indebted economic agents. While their income (be it business income of individuals' income) drops, debts stay unchanged as their contracts are specified in nominal terms.

The above arguments, however, do not hold unconditionally. Selgin (1997, 1999) showed that the results change dramatically when the source of deflation is not a drop in aggregate demand, but on the contrary a rise in productivity. Suppose that firms' investments have increased labour productivity and cut unit costs, so that additional output is now profitable which was not profitable before. Firms sell this output by cutting prices and thus reaching more marginal demand. Consider now the first argument above which states that as output prices are expected to go down, the real interest rate goes up which makes current consumption and current investment more expensive. If productivity growth is the reason for deflation, however, higher real interest rates may only be a reflection of higher real incomes and higher real return on investment. Higher real interest rates may not, on average, put additional burden on new debts because the debtors themselves have bid up the real interest rates as they now expect higher real incomes and higher return on each invested dollar.[49]

The second argument states that firms face a squeeze of profits if output prices go down while wages cannot adjust downward. Yet, if the reason for the drop in output prices is the

[49] See Footnote 20 for a potential weakness in this reasoning by Selgin.

firms' own decision to cut them thanks to lower unit costs, it is intuitive that no such squeeze happens. In addition, in this case nominal wages do *not* have to adjust downward. The real wage w/p has increased (nominal wage w stayed unchanged, while prices p dropped), but this increase only mirrors increased labour productivity. Therefore, the firms still pay the same real wage per unit of output.

Finally, the debt-deflation argument states that firms face an increase in the real value of debt without a corresponding increase in their real income. If the source of output price deflation is increased productivity, then real incomes rise, too, because firms have cut prices precisely to reach more marginal demand in a situation where lower unit costs allow them to. In other words, they have undertaken the price cuts to increase their real incomes. As a result, the discrepancy between real income and real liabilities does not have to appear.[50]

The above reasoning underscores that the deflation-recession links, which may otherwise hold, could lose much ground if the primary source of deflation is productivity improvement. Echoing Selgin, authors such as Reisman (1998), Salerno (2003) and Bagus (2015) have called for strict distinguishing between demand-driven and supply-driven deflation. They highlight that 'deflation' is a single term that describes the end result, but hides two completely different phenomena: a drop in nominal demand from consumers on one hand and a rise in productivity on the other.[51]

Balassa-Samuelson effect

By contrast, some studies such as Eichengreen, Park and Shin (2016) highlight a different view on the relationship between inflation and productivity, represented by the Balassa-Samuelson effect. This effect links countries with fast-growing productivity to higher inflation in case they are open to international trade. The first condition for this is to have a country with tradable goods and non-tradable goods sectors. Productivity is likely to increase more in the tradables sector compared to the non-tradables sector, since it is easier to achieve efficiency gains in the production of goods than in the provision of services. The second condition is that the prices in the tradables sector are determined on the world market and are therefore exogenous to the country in question. As a result, in the tradables sector the productivity gains do not translate into lower output prices (as these are set on the world stage), but instead into higher nominal wages since the physical marginal product increases and output prices stay unchanged. However, rising nominal wages in the tradables sector push upwards also the wages in the non-tradables sector as employers in the non-tradables sector want to keep their workforce. In order for profitability to remain roughly the same in the two sectors, prices in the non-tradables sector will have to rise. Since aggregate price indices are weighted averages of tradable and non-tradable goods, the overall price level will increase.

For example, Guerineau and Guillamont Jeanneney (2005) asserted that the this mechanism was operational in China at the turn of the century when it displayed several years of deflation. They reasoned that since productivity gains lead to higher prices, deflation in China at that

[50] This would not hold in case where some firms cut prices thanks to improved productivity but other firms from the same sector, which were not able to increase productivity, have to accept the lower output price. The reasoning assumes an average, representative firm that improves productivity and cuts prices.

[51] A detailed classification of deflation is provided in Salerno (2003).

time (1998–2002) was the result of a slowdown in productivity growth, not its acceleration.[52] Therefore, this reasoning runs counter the growth deflation theory described above. Since this chapter deals with data from the Czech Republic, which is a small, open economy, the Balassa-Samuelson effect could well be in place.

Scope of analysis

We use sector data on the Czech economy between 1993 and 2015 to look at prices and productivity. Although firm-level data are not available, we think that sector data are a good substitute since firms in one sector typically display similar price dynamics. In Chapter 4 we documented on the same data for the Czech economy that there is a negative and statistically significant relationship between the long-run (average) sector inflation rate and its growth of output and of gross value added. That is, sectors with deflation or below-average inflation show faster growth in output and gross value added. We hypothesize that this result could be due to productivity improvements. Here, we investigate this hypothesis by looking directly at productivity in sectors of the Czech economy and its link to prices. If the results confirm the hypothesis, it would suggest that a sizable part of deflation observed in our data indeed resulted from productivity improvements, constituting the 'good' type of deflation.

If this is confirmed, it would not be at odds with the Balassa-Samuelson effect, in our view. The reason is that our analysis focuses on sectors, not countries. While in the case of countries the Balassa-Samuelson effect implies that those with quicker productivity growth should inflate faster, the same does not apply to sectors within one economy. Rather the opposite holds: it is precisely the non-tradables sectors with slow-growing productivity that inflate in reaction to the growth of productivity in the tradables sector. Therefore, if there is an inverse empirical link between sector price growth and sector productivity growth, it does not run counter the Balassa-Samuelson effect. In a sector setting, the Balassa-Samuelson effect is rather complementary to the supply-side deflation view.

5.3 Modeling the Link between Productivity and Inflation

Productivity can be understood in a broader sense as a measure of efficiency since it tells us how much of an input a firm (or a sector) needs to produce its output. At the same time, microeconomic efficiency analysis frequently uses *ranking* methods because one of the ways how to assess a firm's efficiency is to rank its ratio of output to inputs relatively to the best (most efficient) firm in a peer group. One such method is data envelopment analysis. Thanks to the proximity of productivity to efficiency, we extend the use of envelopment analysis to our purpose. In this section, we first introduce a nonparametric estimator of efficiency and its application to productivity, then explain how it can be linked to an 'environmental' variable—in our setting, the change of prices—and then present our variables.

[52] One could, however, doubt about the fulfillment of Balassa-Samuelson conditions in the case of China. Its dominance in the production of certain export goods has become so significant that it seems unlikely that it would be a pure price-taker of world prices.

5.3.1 Nonparametric Estimator of Efficiency and Productivity

Our model is based on data envelopment analysis, a standard method in the literature for nonparametric modeling of production frontiers and measuring efficiency on the microeconomic level. We first present the standard application for efficiency and then show its use in our setting.

For the purpose of our analysis we work with one-dimensional input x and output y, of which all theoretically feasible combinations (x, y) constitute the economy's production possibility set Ψ. It is straightforward to mathematically rank firms (x, y) based on their distance from the boundary of Ψ, resulting in input-oriented efficiency score θ:

$$\theta(x, y) = \inf\{\theta \mid (\theta x, y) \in \Psi\}.$$

This theoretical model can be turned into a statistical model allowing robust inference by assuming random variables $\mathcal{X}, \mathcal{Y}$, which are observed as the sample $(X_i, Y_i), i = 1, \ldots, n$. Statistical analysis of the set Ψ assumes a joint probability measure characterized by the cumulative distribution function for $(x, y) \in \Psi$:

$$H_{\mathcal{X}\mathcal{Y}}(x, y) = \Pr(\mathcal{X} \leq x, \mathcal{Y} \geq y).$$

Probability measure H allows us to define conditional distribution function

$$F_{\mathcal{X}|\mathcal{Y}}(x \,|\, y) = \Pr(\mathcal{X} \leq x \,|\, \mathcal{Y} \geq y) = \frac{\Pr(\mathcal{X} \leq x, \mathcal{Y} \geq y)}{\Pr(\mathcal{Y} \geq y)},$$

from which the statistical input-oriented efficiency θ ranking is derived as

$$\theta(x, y) = \inf\{\theta \mid F_{\mathcal{X}|\mathcal{Y}}(\theta x \,|\, y) > 0\}.$$

Moving to statistical inference from sample $(X_i, Y_i), i = 1, \ldots, n$, the conditional probability $F_{\mathcal{X}|\mathcal{Y}}(x \,|\, y)$ can be estimated by computing

$$\widehat{F}_{\mathcal{X}|\mathcal{Y},n}(x \,|\, y) = \frac{\sum_{i=1}^{n} I(X_i \leq x, Y_i \geq y)}{\sum_{i=1}^{n} I(Y_i \geq y)},$$

where $I(\cdot)$ is the indicator function. From this it can be derived that the estimator $\hat{\theta}_n(x, y)$ of $\theta(x, y)$ is given by

$$\begin{aligned} \hat{\theta}_n(x, y) &= \inf\{\theta \mid \widehat{F}_{\mathcal{X}|\mathcal{Y}}(\theta x | y) > 0\} = \\ &= \inf\{\theta \mid (\theta x, y) \in \widehat{\Psi}_{\text{FDH}}\} = \min_{i|Y_i \geq y} \left\{ \left(\frac{X_i}{x} \right) \right\}, \end{aligned}$$

the last expression being the free disposal hull (FDH) estimator of efficiency.

5.3.2 Robust and Conditional Modifications

The above free disposal hull estimation is known to be highly sensitive to outliers. However Cazals *et al.* (2002) have developed a robust variant of this methodology called order-m efficiency measure. Order-m estimation is based on the simple idea of comparing each firm to a

randomly generated subset Ψ_m of Ψ, m being the size of the subset. If efficiency measurements are repeated for several draws of Ψ_m, the final efficiency score is then obtained as the expected value of these measurements.

The summary below is based on Daraio and Simar (2005). It can be shown that the order-m efficiency score (eqs. 2.9-2.10 in 2005) is computed as

$$\begin{aligned}\theta_m(x,y) &= \int_0^\infty \left(1 - F_{\mathcal{X}|\mathcal{Y}}(ux \,|\, y)\right)^m \mathrm{d}u \\ &= \theta(x,y) + \int_{\theta(x,y)}^\infty \left(1 - F_{\mathcal{X}|\mathcal{Y}}(ux \,|\, y)\right)^m \mathrm{d}u\end{aligned}$$

and its estimator is given by (eqs. 2.12-2.13 in 2005)

$$\begin{aligned}\hat{\theta}_{m,n}(x,y) &= \int_0^\infty \left(1 - \widehat{F}_{\mathcal{X}|\mathcal{Y},n}(ux \,|\, y)\right)^m \mathrm{d}u \\ &= \hat{\theta}_n(x,y) + \int_{\hat{\theta}_n(x,y)}^\infty \left(1 - \widehat{F}_{\mathcal{X}|\mathcal{Y},n}(ux \,|\, y)\right)^m \mathrm{d}u. \qquad (5.1)\end{aligned}$$

Daraio and Simar (2005) also derive the treatment of efficiency conditional on external variables or environmental factors z. Assuming that z is also represented by a random variable $\mathcal{Z}$ allows us to write the conditional distribution function $F_{\mathcal{X}|\mathcal{Y},\mathcal{Z}}(x \,|\, y, z) = \Pr(\mathcal{X} \leq x | \mathcal{Y} \geq y, \mathcal{Z} = z)$. This function can be empirically estimated using kernel estimation as follows

$$\widehat{F}_{\mathcal{X}\,|\,\mathcal{Y},\mathcal{Z},n}(x \,|\, y, z) = \frac{\sum_{i=1}^n I(X_i \leq x, Y_i \geq y) \cdot K\left(\frac{z - Z_i}{h_n}\right)}{\sum_{i=1}^n I(Y_i \geq y) \cdot K\left(\frac{z - Z_i}{h_n}\right)},$$

where $K(\cdot)$ is a probability kernel and h_n the bandwidth. Once the distribution function is estimated, the conditional counterpart to traditional FDH efficiency estimator, as well as the counterpart to the order-m efficiency score and its estimator are straightforward

$$\begin{aligned}\hat{\theta}_n(x,y \,|\, z) &= \inf\{\theta \mid \widehat{F}_{\mathcal{X}\,|\,\mathcal{Y},\mathcal{Z},n}(\theta x \,|\, y, z) > 0\}, \\ \theta_m(x,y \,|\, z) &= \int_0^\infty \left(1 - F_{\mathcal{X}|\mathcal{Y},\mathcal{Z}}(ux \,|\, y, z)\right)^m \mathrm{d}u, \\ \hat{\theta}_{m,n}(x,y \,|\, z) &= \int_0^\infty \left(1 - \widehat{F}_{\mathcal{X}|\mathcal{Y},\mathcal{Z},n}(ux \,|\, y, z)\right)^m \mathrm{d}u. \qquad (5.2)\end{aligned}$$

We evaluate the integrals in eqs. 5.1 and 5.2 numerically in the package OCTAVE, using adapted MATLAB routines kindly provided by Daraio and Simar (2005).

5.3.3 Impact of Environmental Variables

The purpose of the above model is to understand the impact of z on the ranking of individual observations within the possibility set Ψ. This is achieved by comparing estimated conditional and unconditional efficiency. If we compare the ratio of measured conditional and unconditional efficiency with observed z, we can eventually evaluate whether a given factor z works as an additional quasi-input which can be employed in production (enhancing production),

or whether it works as an additional quasi-output which has to be delivered by production (limiting production).

We employ a simple linear model as follows

$$\frac{\hat{\theta}_{m,n}(x, y \,|\, z)}{\hat{\theta}_{m,n}(x, y)} = \alpha + \beta \cdot z + \epsilon. \tag{5.3}$$

As noted in Daraio and Simar (2005), $\beta > 0$ implies that z is *limiting* production, while $\beta < 0$ implies that z is *enhancing* production. While this might appear counterintuitive, it is important to remember that unfavourable z appears as an additional output in the conditional score $\hat{\theta}_{m,n}(x, y \,|\, z)$, so that higher z translates into conditional efficiency score being higher than the unconditional one (the conditional score evaluates this extra output z as the firm being more efficient). Conversely, favourable z appears as an additional input in the conditional score $\hat{\theta}_{m,n}(x, y \,|\, z)$, so that higher z translates into lower efficiency.

5.3.4 Productivity and Inflation

Let us interpret the presented efficiency model in terms of productivity, so that we can evaluate the relationship between inflation and productivity growth. Recall that in mathematical terms, any efficiency score, including $\theta(x, y)$, is by definition essentially a ratio of outputs and inputs. In the same manner, OECD (2001) defines labour productivity as the ratio of a quantity index of gross output and a quantity index of labour. In this definition, gross output can alternatively be replaced by gross value added so that the fraction better reflects the contribution of labour to gross profits.

Hence it is straightforward to base our productivity analysis on ratios of observations on gross output (denoted Out) and gross value added (GVA) as two types of outputs, and on employed hours worked (Emp) as inputs. These variables form the respective ratios in the efficiency model.

Our interest lies in the relationship between the growth rate of productivity and the growth rate of prices. We therefore adjust the efficiency scores and Equation 5.3 to include rates of change of our variables. For example, for the case of labour productivity related to output, we have

$$\frac{\hat{\theta}_{m,n}(\mathsf{emp}, \mathsf{out} \,|\, \mathsf{p})}{\hat{\theta}_{m,n}(\mathsf{emp}, \mathsf{out})} = \alpha + \beta_{\mathsf{out}} \cdot \mathsf{p} + \epsilon, \tag{5.4}$$

where lower case notation indicates growth rates of the respective variables and p is the rate of change of sector output deflator P. Analogously for the case of labour productivity related to gross value added we have

$$\frac{\hat{\theta}_{m,n}(\mathsf{emp}, \mathsf{gva} \,|\, \mathsf{p})}{\hat{\theta}_{m,n}(\mathsf{emp}, \mathsf{gva})} = \alpha + \beta_{\mathsf{gva}} \cdot \mathsf{p} + \epsilon. \tag{5.5}$$

With this reformulation, we employ the idea of productivity in efficiency scores and use it in a dynamic fashion. The reason is that rather than studying levels of productivity and levels

of prices, we want to know about the change in productivity in response to a change in prices. In Equation 5.4, the growth in prices p does not only have a purely econometric function of an 'environmental variable' whose effect we study. Its economic interpretation stems from the logic presented in Section 5.2 above: decreasing prices may be a proxy for the sector's investment and falling unit costs, while increasing prices may be a symptom of lack of investment or its slow pace.

5.3.5 Data and Variables

Our data is from the National Accounts statistics of the Czech Statistical Office (2017). It consists of macroeconomic indicators on output, inputs and prices of 86 sectors of the Czech economy over 1993–2015. The sectors are classified according to the NACE classification and they include both goods-producing sectors and services.

The variables output (Out), gross value added (GVA) and employed hours worked (Emp) are all in real terms, while the output price deflator (P) represents nominal prices. We prefer employed hours worked instead of the number of employed persons because firms often adjust their needed labour input by adding or cutting shifts or adjusting their length, rather than by immediately hiring or laying off employees. Employed hours worked therefore better reflect the true labour input in production from employees.

Our sample has 23 years in levels, which implies 22 years of growth rates. Thus the sample consists of 22 periods and 86 sectors, which would give 1892 observations. However, the sample has some missing observations and one variable (employed hours worked) does not have data for the years 1993 and 1994. We also slightly restrict outliers in the sample. The annual percent change in the sector price deflator p has values ranging from -30% to 63.8% in the whole sample. The extreme rates of inflation or deflation are most often from sectors such as mining and extraction, where output prices follow the volatile prices of commodities. However, we omit these extreme outliers for two reasons. First, such outliers easily distort the results of regressions while they are very scarce and do not represent typical price movements. Second, such big jumps of prices have almost certainly nothing to do with year-on-year productivity changes. They rather reflect swings of prices on world markets. Therefore, we follow the practice of other authors (Atkeson and Kehoe, 2004, Ichiue and Nishiguchi, 2014, and Bachmann, Berg and Sims, 2015) and leave out observations with price growth in excess of 20% in absolute value. This adjustment causes a loss of only 37 observations.

Overall, a model with price growth, output growth and growth in employed hours worked has 1492 observations. The alternative model where output growth is replaced by growth in GVA has 1400 observations.

5.4 Results

5.4.1 Time Averages

We perform two sets of calculations. As a first look whether there is a link, we start with time averages over the period 1993–2015 for all variables, neglecting any missing values, so that this

calculation condenses all information from the data set.[53] Because we use compound annual growth rate of variables (geometric mean), extreme *annual* observations of price change are not of great concern. Steep increases in one year are often offset by similarly steep drops in the following one, so the geometric mean is unaffected. We then evaluate productivity rankings for the 86 industries and the impact of average price change on those rankings. We set order-m to $m = 20$ and employ Gaussian kernel for the calculation of conditional efficiency. For bandwidth selection we follow the k-nearest neighbour (k-NN) procedure proposed by Daraio and Simar (2005, Section 4.3), where we find $k = 11$. The k factor is used to find h_{Z_i} such that there are k points satisfying $|Z_i - Z_j| < h_{Z_i}$. Note that we also tested small changes in k which did not change our results. A well selected factor k is mainly important for statistical validity of our results.

Results shown in Table 5.1 imply that industries with higher average output price change recorded lower labour productivity growth. Because β_{out} is positive, sector price inflation worked as a negative input into labour productivity growth.

Table 5.1: Time averages: Productivity based on output

	Coeff. est.	Std. Error	t-statistic	p-value
α	0.81412	0.09224	8.826	1.33e-13
β_{out}	0.18701	0.08946	2.090	0.0396
♯ of obs.	86			

Residual standard error: 0.01469 on 84 degrees of freedom.
Multiple R-squared: 0.04945, Adjusted R-squared: 0.03814
F-statistic: 4.37 on 1 and 84 DF, p-value: 0.0396

5.4.2 Panel Data

In the second calculation, we use the whole data set without outliers and missing observations, as explained above in Section 5.3.5. This time we set order-m to $m = 300$ and using the k-NN procedure we find $k = 290$. Results are shown in Table 5.2. The sign of β_{out} is again positive, which implies a negative impact of inflation on labour productivity. Statistical significance is higher in this case, reinforcing our result across periods as well as industries. The same calculation is presented for labour productivity measured against gross value added, as shown in Table 5.3 with $m = 300$ and $k = 270$.

In order to evaluate the impact of inflation on productivity, we need to interpret the coefficient β within the respective ranking move. For the case of output labour productivity, one percentage point of additional output inflation implies two tenths of a percentage point in the ranking ratio ($0.01 \times \beta_{\mathsf{out}} = 0.01 \times 0.2 = 0.002$).

Efficiency scores θ are normed to be between zero and one, even though due to the statistical approach used in our model some ranking scores $\hat{\theta}_{m,n}(\mathsf{emp}, \mathsf{out})$ and $\hat{\theta}_{m,n}(\mathsf{emp}, \mathsf{out} \,|\, \mathsf{p})$ are

[53] We use the slightly shorter period 1995–2015 in the model with employed hours worked since this variable is unavailable for 1993 and 1994.

Table 5.2: Panel data: Productivity based on output

	Coeff. est.	Std. Error	t-statistic	p-value
α	0.81510	0.01152	70.73	<2e-16
β_{out}	0.19243	0.01121	17.16	<2e-16
♯ of obs.	1492			

Residual standard error: 0.01855 on 1490 degrees of freedom.
Multiple R-squared: 0.1651, Adjusted R-squared: 0.1645.
F-statistic: 294.6 on 1 and 1490 DF, p-value: < 2.2e-16.

Table 5.3: Panel data: Productivity based on GVA

	Coeff. est.	Std. Error	t-statistic	p-value
α	0.93115	0.01892	49.203	<2e-16
β_{gva}	0.09297	0.01841	5.051	4.99e-07
♯ of obs.	1400			

Residual standard error: 0.0276 on 1398 degrees of freedom.
Multiple R-squared: 0.01792, Adjusted R-squared: 0.01722.
F-statistic: 25.51 on 1 and 1398 DF, p-value: 4.987e-07.

slightly higher than one. As the regression shows, statistically it holds that $\hat{\theta}_{m,n}(\mathsf{emp}, \mathsf{out} \,|\, \mathsf{p}) > \hat{\theta}_{m,n}(\mathsf{emp}, \mathsf{out})$, and the average ratio of both rankings is very close to one, namely 1.013. Because each of the rankings is typically less than one, the 0.002 change in the ratio translates into a slightly higher impact on the wedge between the two rankings. In other words, the conditional and unconditional rankings are slightly farther apart from the 2×10^{-3} order. Therefore, for either one of the individual rankings (holding the other ranking constant) we can write:

$$\frac{\partial \hat{\theta}_{m,n}}{\partial \mathsf{p}} > 0.002.$$

Finally we have to recall that θ rankings are just a rescaling of deterministic labour productivity to the interval between zero and one. A deterministic calculation of labour productivity growth rates as $\mathsf{Lprod} = \frac{\mathsf{out}}{\mathsf{emp}}$ yields a ratio ≈ 1.23 times higher than $\hat{\theta}_{m,n}(\mathsf{emp}, \mathsf{out})$. (That is, the average of ratios of deterministic Lprod and robust $\hat{\theta}_{m,n}(\mathsf{emp}, \mathsf{out})$.) Therefore,

$$\frac{\partial \, \mathsf{Lprod}}{\partial \mathsf{p}} > 0.002 \times 1.2 = 0.0024.$$

We conclude that one percentage point of sector price inflation is empirically associated with at least 0.24 percentage points lost in labour productivity growth. This may look small given the fact that based on our data, average annual labour productivity growth in the Czech economy as a whole was 3.7%. However, the standard deviation of sector inflation in the sample is 4.32 percentage points. Therefore, two observations that are one standard deviation of sector

inflation apart from each other would have a difference in productivity growth of roughly 1 percentage point ($0.24 \times 4.32 = 1.04$), which is not negligible. In other words, sector deflation or below-average inflation is linked to higher productivity growth, which is in line with the hypothesis that lower prices across sectors may partially be a reflection of investment and lower unit costs.

Analogously for labour productivity based on gross value added, the impact is about half as large, or 0.12 percentage points in lost productivity growth for one additional percentage point of sector price inflation.

5.5 Summary

The present chapter extended the inquiry started in Chapter 4 by looking at a potential link of sector price growth to productivity. Using sector data on the Czech economy, we computed labour productivity for each sector and year and used a robust nonparametric method to rank each observation according to the productivity (efficiency) achieved relative to other observations, obtaining efficiency scores. We see two contributions of the present chapter.

First, we have found that observations ranking as having higher productivity are generally associated with lower price growth. This sheds additional light on the evidence from long-run time averages in Chapter 4 showing negative link between sector inflation and sector output over the same period. The present results may indicate that sectors with rising productivity in the Czech economy have tended to have lower growth of their output prices. This would constitute one specific type of supply-led sector deflation. The results in this section are also consistent with the Balassa-Samuelson effect. Sectors with low or no productivity growth display higher sector inflation, which is in line with the hypothesis that inflation appears in sectors with stagnant productivity as they compete for workers by raising wages and prices. We note that after constructing the efficiency scores, we have only used simple regressions to link productivity with prices. We also restricted our attention to the Czech Republic. Therefore, we do not conclude that productivity is generally the major driver behind differences in sector inflation rates. We only show that the link in the case of the Czech Republic is present.

Second, this chapter has shown a possibility how to approach productivity from an estimation point of view. If productivity is understood as a form of efficiency in real terms, then tools of nonparametric robust estimation are possible to employ and the link to prices (or other variables) can be achieved through the addition of an 'environmental variable'. If the link of productivity with prices is studied more extensively (which has not been the case so far), the present approach may open up new possibilities.

Chapter 6

Conclusion

The goal of the present thesis has been to extend the knowledge about the link between deflation and output growth. Two approaches were taken.

First, in Chapter 3 I used both demand side and supply side control variables to separate the link between price inflation and growth as such from other effects, possibly due to money supply growth or growth of costs of production (proxied by oil prices). This was an important missing piece in the existing empirical research. The results show that the contemporaneous link between inflation and GDP growth turns out to be slightly negative and statistically significant in the full sample, while other studies that do not have the mentioned control variables report either a slightly positive or roughly zero link. (The negative and significant result subsides after leaving out the gold standard, but still does not become positive and significant.) Interestingly, similar results are posted by restricted samples only with deflation: the present study still finds a slight negative link between price growth and output growth, while other studies without the controls find a tangible positive link. This may be an indication that control variables, especially money supply, might be crucial in finding the link. The Great Depression is the only subsample that paints a very different picture, in line with other studies. Here, even after the addition of control variables the positive and significant link between inflation and output growth remains. This may suggest that there can be special circumstances in which there is indeed a link between price deflation as such and recession, possibly related to expectations. Therefore, this 'pure' link between price growth and output growth cannot be completely ruled out, although it appears to be empirically very rare. Apart from short-run associations, VECM did not uncover a significant long run effect of inflation on growth in any of the samples.

Second, in Chapter 4 I presented a new approach based on sector data on price growth and output growth. This disaggregated approach has the advantage of providing modern-day data on price deflation of products which are not available on the aggregate level. On the other hand, by their nature these data lack relevance for policy that aggregate data may have. Therefore, the focus has been on inspecting the microeconomic core of deflation-recession theories and what sector data may clarify about them. The central result from sector panel data is that growth of quantity demanded does not seem to be positively linked to the growth of prices of the underlying goods or services, controlling for the simultaneity with supply by using instrumental variables. This result holds over most specifications and samples. Therefore, from a microeconomic point of view, I do not find evidence for the hypothesis that quantity demanded would decrease in reaction to price drops of the underlying product. This result is consistent with the macroeconomic part. The sector panel analysis limits itself to contemporaneous links, however. Different results with lags are therefore not ruled out.

Last but not least, a more technically oriented analysis in Chapter 5 showed on sector data that productivity may be approached as efficiency and non-parametric efficiency-score method

applied. This method showed a possible link between sector deflation or below-average inflation and productivity improvements. Such a result could be interpreted both as presence of some degree of productivity-led price reductions or of the workings of the Balassa-Samuelson effect.

There are, however, important qualifications. The present work has dealt with realized inflation and deflation, not inflationary or deflationary expectations. In some cases, deflation expectations may coincide with realized, observable deflation, either at present or with a lag. However, there may be cases of deflation which is underway but which is not accompanied by deflation expectations. If some deflation-recession arguments (such as postponement of spending) rely more on deflationary expectations than deflation itself, then these instances are not fully covered by the present work. That is, empirical research may find that there is not a strong link between recession and deflation, but this may not refute a theory based on deflationary expectations. For example, monetary policy with a record of achieving above-zero inflation might prevent deflationary expectations even if actual deflation—presumably for a short period—occurs. Therefore, the results of the present empirical research are not necessarily evidence against theories which are based on expectations. As discussed in Chapter 2, however, obtaining inflation expectations as a replacement for actual inflation is complicated and has risks of its own. Another caveat for the macroeconomic part is that some subsamples, such as a restricted sample of only deflation observations after the classical gold standard, do not have many observations of consecutive, persistent deflation. The same applies to a potentially interesting sample with only observations fulfilling the zero-lower bound condition. Here, again, deflation observations are hard to find. For the sector approach, an important qualification is that by its nature, it is much more oriented to the foundations of deflation-recession theories than policy-oriented.

Several directions could be promising for future research. One way would be the expansion of use of inflation expectations, which have so far not become dominant and which are not easily obtained. However, these would go to the heart of the question if there is an upward-sloping, kinked aggregate demand curve. Research using realized inflation or deflation can shed some light on these theories, but cannot completely answer them.

Another way, which this thesis has suggested, is a more disaggregated approach. Discussion in this thesis has shown that deflation-recession theories often use ultimately microeconomic arguments about consumers and firms. The key arguments why deflation could be harmful for growth concern the reactions of consumers or lack of adjustment by firms. Therefore, it would be useful if empirical research could reach closer to the consumer or firm. A particularly interesting direction of empirical research would be to also reverse the perspective from input-output data used in the present work to demand-side data on consumer choice and price growth of demanded items. In my view, both the aggregate and disaggregated approach still offer ample possibilities for further research in the area of deflation and economic growth, which has so far received less attention than it deserves.

References

Arellano, M. and Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *The Review of Economic Studies*, 58(2):277–297. doi:10.2307/2297968.

Atkeson, A. and Kehoe, P. J. (2004). Deflation and Depression: Is There an Empirical Link? *American Economic Review*, 94(2):99–103. doi:10.1257/0002828041301588.

Auerbach, A. J. and Obstfeld, M. (2004). Monetary and Fiscal Remedies for Deflation. *American Economic Review*, 94(2):71–75. doi:10.1257/0002828041301948.

Baba, N. et al. (2005). Japan's Deflation, Problems in the Financial System and Monetary Policy. *BIS Working Paper 188*.

Bachmann, R., Berg, T. O., and Sims, E. R. (2015). Inflation Expectations and Readiness to Spend: Cross-Sectional Evidence. *American Economic Journal: Economic Policy*, 7(1):1–35. doi:10.1257/pol.20130292.

Bagus, P. (2003). Deflation: When Austrians Become Interventionists. *The Quarterly Journal of Austrian Economics*, 6(4):19–35. doi:10.1007/s12113-003-1002-6.

Bagus, P. (2015). *In Defense of Deflation.* Springer. Financial and Monetary Policy Studies (41). doi:10.1007/978-3-319-13428-4.

Ball, L. and Mankiw, N. G. (1995). Relative-Price Changes as Aggregate Supply Shocks. *The Quarterly Journal of Economics*, 110(1):161–193. doi:10.2307/2118514.

Bank of England (2018). A Millenium of Macroeconomic Data. https://www.bankofengland.co.uk/statistics/research-datasets Retrieved on April 22, 2018.

Bank of Japan. (2017). "Price Stability Target" of 2 Percent and "Quantitative and Qualitative Monetary Easing with Yield Curve Control". https://www.boj.or.jp/en/mopo/outline/qqe.htm/.

Barro, R. (1995). Inflation and Economic Growth. *Bank of England Quarterly Bulletin*, 35(2):166–176.

Beckworth, D. (2007). The Postbellum Deflation and Its Lessons for Today. *The North American Journal of Economics and Finance*, 18(2):195–214. doi:10.1016/j.najef.2006.12.003.

Benhabib, J. and Spiegel, M. M. (2009). Moderate Inflation and the Deflation-Depression Link. *Journal of Money, Credit and Banking*, 41(4):787–798. doi:10.2139/ssrn.1004591.

Bernanke, B. S. (1995). The Macroeconomics of the Great Depression: A Comparative Approach. *Journal of Money, Credit and Banking*, 27(1):1–28. doi:10.2307/2077848.

Bernanke, B. S. (2002). *Deflation – Making Sure It Doesn't Happen Here.* Speech before the National Economists Club, Washington, D.C., November 21.

Bernanke, B. S. (2003). Downside Danger. *Foreign Policy*, (139):74–75. doi:10.2307/3183740.

Bernanke, B. S. and Gertler, M. (1989). Agency Costs, Net Worth, and Business Fluctuations. *American Economic Review*, 79(1):14–31.

Bloomberg (2018). World Economic Statistics. Bloomberg Professional Services. Retrieved on April 23, 2018.

Bordo, M. D. (2018). Financial Crises Database. http://sites.google.com/site/michaelbordo/home4. Retrieved on April 21, 2018.

Bordo, M. D. and Filardo, A. (2004). Deflation and Monetary Policy in a Historical Perspective: Remembering the Past or Being Condemned to Repeat It? *NBER Working Paper 10833.* doi:10.3386/w10833.

Bordo, M. D. and Filardo, A. (2005). Deflation and Monetary Policy in a Historical Perspective: Remembering the Past or Being Condemned to Repeat It? *Economic Policy*, 20(44):800–844. doi:10.1111/j.1468-0327.2005.00151.x.

Bordo, M. D., Lane, J. L., and Redish, A. (2004). Good versus Bad Deflation: Lessons from the Gold Standard Era. *NBER Working Paper 10329.* doi:10.3386/w10329.

Bordo, M. D. and Redish, A. (2003). Is Deflation Depressing? Evidence from the Classical Gold Standard. *NBER Working Paper 9520.* doi:10.3386/w9520.

Borio, C., Erdem, M., Filardo, A., and Hofmann, B. (2015). The Costs of Deflations: A Historical Perspective. *BIS Quarterly Review*, 20(1):31–54. doi:10.2139/ssrn.1004591.

Borio, C. and Filardo, A. J. (2004). Looking Back at the International Deflation Record. *The North American Journal of Economics and Finance*, 15(3):287–311. doi:10.1016/j.najef.2004.08.001.

British Petroleum (2018). Statistical Review of World Energy. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html Retrieved on April 21, 2018.

Burdekin, R. C. K. and Siklos, P. L. (2004). *Deflation. Current and Historical Perspectives.* Cambridge University Press.

Bureau of Economic Analysis (2018). Industry Economic Accounts. https://www.bea.gov/industry/gdpbyind_data.htm Retrieved on June 2, 2018.

Buttet, S. and Roy, U. (2014). A Simple Treatment of the Liquidity Trap for Intermediate Macroeconomics Courses. *The Journal of Economic Education*, 45(1):36–55. doi:10.1080/00220485.2014.859959.

Cargill, T. F. and Parker, E. (2004a). Price Deflation and Consumption: Central Bank Policy and Japan's Economic and Financial Stagnation. *Journal of Asian Economics*, 15(3):493–506. doi:10.1016/j.asieco.2004.04.001.

Cargill, T. F. and Parker, E. (2004b). Price Deflation, Money Demand, and Monetary Policy Discontinuity: A Comparative View of Japan, China, and the United States. *North American Journal of Economics and Finance*, 15(1):125–147. doi:10.1016/j.najef.2003.11.002.

Carlton, D. W. (1986). The Rigidity of Prices. *American Economic Review*, 76(4):637–658.

Carroll, C. H. (1972 [1964]). *Organization of Debt into Currency and Other Papers.* New York: Arno Press & The New York Times.

Casiraghi, M. and Ferrero, G. (2015). Is Deflation Good or Bad? Just Mind the Inflation Gap. *Banca d'Italia: Questioni di Economia e Finanza. Occasional Paper No 268.*

Castañeda, J. E. and Schwartz, P. (2012). Non-Monetary Deflations and Price Stability in Spain 1868-1914. Conference Paper at DAMIN Conference on Money and the Economy in the 19th Century; ENS, Paris. https://www.researchgate.net/publication/266390590_Non-monetary_deflations_and_price_stability_in_Spain_1868-1914.

Cazals, C., Florens, J.-P., and Simar, L. (2002). Nonparametric Frontier Estimation: A Robust Approach. *Journal of Econometrics*, 106:1–25.

Cecchetti, S. G. (1992). Prices During the Great Depression: Was the Deflation of 1930–32 Really Unanticipated? *American Economic Review*, 82(1):141–156.

Christensen, J. (2009). Inflation Expectations and the Risk of Deflation. *Federal Reserve Bank of San Francisco Economic Letter*, (34).

Czech National Bank. (2017). Inflation Targeting in the Czech Republic. https://www.cnb.cz/en/monetary_policy/inflation_targeting.html.

Czech National Bank (2018). ARAD Database. https://www.cnb.cz/docs/ARADY/HTML/index.htm Retrieved on July 10, 2018.

Czech Statistical Office. (2017). Database of National Accounts. http://apl.czso.cz/pll/rocenka/rocenkavyber.socas Retrieved on January 11, 2017.

Daraio, C. and Simar, L. (2005). Introducing Environmental Variables in Nonparametric Frontier Models: A Probabilistic Approach. *Journal of Productivity Analysis*, 24:93–121.

Davis, J. S. (2015). The Asymmetric Effects of Deflation on Consumption Spending: Evidence from the Great Depression. *Federal Reserve Bank of Dallas, Globalization and Monetary Policy Institute Working Paper 226.*

DeLong, J. B. (1999). Should We Fear Deflation? *Brookings Papers on Economic Activity*, (1):225–252. doi:10.2307/2534666.

DeLong, J. B. and Summers, L. (1986). Is Increased Price Flexibility Stabilizing? *American Economic Review*, 76(5):1031–44.

Dhyne, E. et al. (2005). Price Setting in the Euro Area: Some Stylized Facts from Individual Consumer Price Data. *ECB Working Paper No 524.*

Diercks, A. M. (2017). The Reader's Guide to Optimal Monetary Policy. Draft as of June 18, 2017. https://ssrn.com/abstract=2989237.

Dotsey, M. (2010). Monetary Policy in a Liquidity Trap. *Federal Reserve Bank of Philadelphia Business Review*, (2):9–15.

Eichengreen, B., Park, D., and Shin, K. (2016). Deflation in Asia: Should the Dangers Be Dismissed? *Asian Development Bank Working Paper No. 490.*

Eichengreen, B. J. (1992). *Golden Fetters: The Gold Standard and the Great Depression, 1919–1939.* Oxford University Press.

Enders, W. (2015). *Applied Econometric Time Series. Fourth edition.* John Wiley & Sons.

European Central Bank. (2017). Monetary Policy. https://www.ecb.europa.eu/mopo/html/index.en.html.

Federal Reserve Bank of St. Louis (2018). FRED Economic Data. https://fred.stlouisfed.org/series/MABMM301USA189S Retrieved on July 10, 2018.

Federal Reserve System. (2012). Federal Reserve Issues FOMC Statement of Longer-Run Goals and Policy Strategy. https://www.federalreserve.gov/newsevents/pressreleases/monetary20120125c.htm.

Federal Reserve System. (2015). Why Does the Federal Reserve Aim for 2 Percent Inflation over Time? https://www.federalreserve.gov/faqs/economy_14400.htm.

Feldstein, M. (2002). Deflation. Speech before the BIS Central Bankers Dinner, Mexico City. https://www.bis.org/review/r021128e.pdf.

Fisher, I. (1933). The Debt-Deflation Theory of Great Depressions. *Econometrica*, 1(4):337–357. doi:10.2307/1907327.

Friedman, M. (1969). *The Optimum Quantity of Money.* In: The Optimum Quantity of Money and Other Essays. Chicago: Aldine.

Friedman, M. (2005). A Natural Experiment in Monetary Policy Covering Three Episodes of Growth and Decline in the Economy and the Stock Market. *Journal of Economic Perspectives*, 19(4):145–150. doi:10.1257/089533005775196787.

Friedman, M. and Schwartz, A. J. (1963a). *A Monetary History of the United States, 1867–1960.* Princeton University Press.

Friedman, M. and Schwartz, A. J. (1963b). Money and Business Cycles. *The Review of Economics and Statistics*, 45(1):32–64. doi:10.2307/1927148.

Groth, C. and Westaway, P. (2009). Deflation. *Bank of England Quarterly Bulletin*, 50(1):37–44.

Guerineau, S. and Guillamont-Jeanneney, S. (2005). Deflation in China. *China Economic Review*, 16(4):336–363. doi:10.1016/j.chieco.2005.03.002.

Guerrero, F. and Parker, E. (2006). Deflation and Recession: Finding the Empirical Link. *Economics Letters*, 93(1):12–17. doi:10.1016/j.econlet.2006.03.029.

Gylfason, T. and Herbertsson, T. T. (2001). Does Inflation Matter for Growth? *Japan and the World Economy*, 13(4):405–428. doi:10.1016/s0922-1425(01)00073-1.

Hamilton, J. D. (1992). Was the Deflation During the Great Depression Anticipated? Evidence from the Commodity Futures Market. *American Economic Review*, 82(1):157–178.

Hayashi, F. and Prescott, E. C. (2002). The 1990s in Japan: A Lost Decade. *Review of Economic Dynamics*, 5(1):206–235. doi:10.1006/redy.2001.0149.

Hayek, F. A. (1931). The "Paradox" of Saving. *Economica*, 11(32):125–169. doi:10.2307/2547921.

Hayek, F. A. (1932). Reflections on the Pure Theory of Money of Mr. J. M. Keynes (continued). *Economica*, (35):22–44. doi:10.2307/2548974.

Hayek, F. A. (1967 [1931]). *Prices and Production.* New Jersey: Augustus M. Kelley Publishers.

Hayek, F. A. (1975 [1933]). *Monetary Theory and the Trade Cycle.* Clifton: Augustus M. Kelley Publishers.

Hayek, F. A. (1990 [1976]). *The Denationalization of Money.* Institute of Economic Affairs.

Hori, M. and Shimizutani, S. (2005). Price Expectations and Consumption under Deflation: Evidence from Japanese Household Survey Data. *International Economics and Economic Policy*, 2(2-3):127–151. doi:10.1007/s10368-005-0030-4.

Hülsmann, J. G. (2008). *Deflation and Liberty.* Ludwig von Mises Institute. Auburn, Alabama.

Humphrey, T. M. (2003). Classical Deflation Theory. *Federal Reserve Bank of Richmond Working Paper 03-13.*

Ichiue, H. and Nishiguchi, S. (2014). Inflation Expectations and Consumer Spending at the Zero Bound: Micro Evidence. *Economic Inquiry*, 53(2):1086–1107. doi:10.1111/ecin.12176.

IMF (2018). International Financial Statistics. http://data.imf.org/?sk=7CB6619C-CF87-48DC-9443-2973E161ABEB Retrieved on April 21, 2018.

Inklaar, R., de Jong, H., Bolt, J., and van Zanden, J. (2018). Rebasing 'Maddison': New Income Comparisons and the Shape of Long-Run Economic Eevelopment. Maddison Project Working Paper 10. https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2018 Retrieved on May 18, 2018.

Ireland, P. (2001). The Real Balance Effect. *NBER Working Paper 8136.* doi:10.3386/w8136.

Japan Cabinet Office (2017). Statistics. http://www.esri.cao.go.jp/index-e.html Retrieved on August 27, 2017.

Japan Statistics Bureau (2018). Statistics Japan. http://www.stat.go.jp/english/data/index.html Retrieved on April 21, 2018.

Johnsson, R. C. B. (2005). Deflation and Japan Revisited. *The Quarterly Journal of Austrian Economics*, 8(1):15–29. doi:10.1007/s12113-005-1014-5.

Jordà, Ò., Schularick, M., and Taylor, A. M. (2017). Macrofinancial History and the New Business Cycle Facts. *NBER Macroeconomics Annual. Edited by Martin Eichenbaum and Jonathan A. Parker.*, 31(1):213–263. doi:10.1086/690241.

Kaza, G. (2006). Deflation and Economic Growth. *The Quarterly Journal of Austrian Economics*, 9(2):95–97. doi:10.1007/s12113-006-1010-4.

Keynes, J. M. (1936). *The General Theory of Employment, Interest and Money.* Palgrave Macmillan.

Kim, S. and Roubini, N. (2000). Exchange Rate Anomalies in the Industrial Countries: A Solution with a Structural VAR Approach. *Journal of Monetary Economics*, 45(3):561–586. doi:10.1016/s0304-3932(00)00010-6.

King, M. (1994). Debt deflation: Theory and evidence. *European Economic Review*, 38(3-4):419–445. doi:10.1016/0014-2921(94)90083-3.

Kovanda, L. and Komrska, M. (2017). Deflace, odklad spotřeby a hospodářské krize: rétorika centrálních bank vs. ekonomická literatura . *Politická ekonomie*, 65(3):351–369. doi:10.18267/j.polek.1148.

Krugman, P. R. (1998). It's Baaack: Japan's Slump and the Return of the Liquidity Trap. *Brookings Papers on Economic Activity*, 29(2):137–205. doi:10.1.1.320.9837.

Kumar, M. S. et al. (2003). Deflation: Determinants, Risks, and Policy Options – Findings of an Interdepartmental Task Force. *International Monetary Fund Occasional Paper 221.* doi:10.5089/9781589062276.084.

Kuroda, H. (2016). *The Battle against Deflation – the Evolution of Monetary Policy and Japan's Experiment.* Speech at Columbia University, New York City, April 13.

Leamer, E. E. (2011). Deflation Dread Disorder "The CPI is Falling!". *The Economists' Voice*, 8(1). doi:10.2202/1553-3832.1819.

López-Villavicencio, A. and Mignon, V. (2011). On the Impact of Inflation on Output Growth: Does the Level of Inflation Matter? *Journal of Macroeconomics*, 33(3):455–464. doi:10.1016/j.jmacro.2011.02.003.

Lucas, R. E. (1972). Expectations and the Neutrality of Money. *Journal of Economic Theory*, 4(2):103–124. doi:10.1016/0022-0531(72)90142-1.

Lucas, R. E. (1973). Some International Evidence on Output-Inflation Tradeoffs. *American Economic Review*, 63(3):326–334.

Lucas, R. E. (1975). An Equilibrium Model of the Business Cycle. *Journal of Political Economy*, 83(6):1113–1144. doi:10.1086/260386.

Maddison, A. (2010). Statistics on World Population, GDP and Per Capita GDP, 1–2008 AD. http://www.ggdc.net/maddison/oriindex.htm. Retrieved on June 20, 2010.

Mankiw, N. G. (2001). The Inexorable and Mysterious Tradeoff Between Inflation and Unemployment. *The Economic Journal*, 111(471):45–61. doi:10.1111/1468-0297.00619.

Mankiw, N. G. (2016). *Macroeconomics. 9th edition.* Worth Publishers.

McCandless, G. T. and Weber, W. (1995). Some Monetary Facts. *Federal Reserve Bank of Minneapolis Quarterly Review*, 19(3):2–11.

Mendoza, E. G. (2006). Lessons from the Debt-Deflation Theory of Sudden Stops. *American Economic Review*, 96(2):411–416. doi:10.1257/000282806777211676.

Mitchell, B. R. (2003). *International Historical Statistics. 4th edition.* Basingstoke: Palgrave Macmillan.

Nickell, S. (1981). Biases in Dynamic Models with Fixed Effects. *Econometrica*, 49(6):1417–1426. doi:10.2307/1911408.

OECD. (2001). Measuring Productivity. OECD Manual. https://www.oecd.org/std/productivity-stats/2352458.pdf.

OECD. (2016). OECD.Stat. http://stats.oecd.org/index.aspx?queryid=36324.

Ohanian, L. E. (2009). What – or Who – Started the Great Depression? *Journal of Economic Theory*, 144(6):2310–2335. doi:10.1016/j.jet.2009.10.007.

Okun, A. M. (1981). *Prices and Quantities: A Macroeconomic Analysis.* Washington, D.C.: The Brookings Institution.

Palley, T. I. (2008). Keynesian Models of Deflation and Depression Revisited. *Journal of Economic Behavior & Organization*, 68(1):167–177. doi:10.1016/j.jebo.2008.02.001.

Patinkin, D. (1965 [1956]). *Money, Interest, and Price. Second Edition.* New York: Harper and Row.

von Peter, G. (2005). Debt-deflation: Concepts and a Stylised Model. *BIS Working Paper 176.*

Phillips, A. W. (1958). The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957. *Economica*, 25(100):283–299. doi:10.2307/2550759.

Pigou, A. C. (1943). The Classical Stationary State. *The Economic Journal*, 53(212):343–351. doi:10.2307/2226394.

Plosser, C. I. (2003). Deflating Deflationary Fears. Shadow Open Market Committee Position Paper. http://www.shadowfed.org/wp-content/uploads/2010/03/plosser_1103_a.pdf.

Reinhart, C. M. and Rogoff, K. S. (2011). From Financial Crash to Debt Crisis. *American Economic Review*, 101(5):1676–1706. doi:10.1257/aer.101.5.1676.

Reisman, G. (1998). *Capitalism. Third edition.* Ottawa, Illinois: Jameson Books.

Romer, C. D. (1992). What Ended the Great Depression? *The Journal of Economic History*, 52(04):757–784. doi:10.1017/s002205070001189x.

Romer, D. (2012). *Advanced Macroeconomics. Fourth edition.* New York: McGraw Hill.

Rothbard, M. (2000 [1963]). *America's Great Depression. Fifth edition.* Auburn: The Ludwig von Mises Institute.

Rothbard, M. N. (1991). Deflation, Free or Compulsory. *The Free Market*, 9(4):1–4.

Salerno, J. T. (2003). An Austrian Taxonomy of Deflation—with Applications to the U.S. *The Quarterly Journal of Austrian Economics*, 6(4):81–109. doi:10.1007/s12113-003-1007-1.

Sanches, D. (2012). The Optimum Quantity of Money. *Federal Reserve Bank of Philadelphia Business Review*, (4):8–15.

Schularick, M. and Taylor, A. M. (2012). Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises, 1870–2008. *American Economic Review*, 102(2):1029–1061. doi:10.1257/aer.102.2.1029.

Selgin, G. (1997). *Less than Zero: The Case for a Falling Price Level in a Growing Economy.* London: Institute of Economic Affairs. IEA Hobart Paper No. 132.

Selgin, G. (1999). A Plea for (Mild) Deflation. *CATO Policy Report*, 21(3).

Seltzer, A. (2010). Did Firms Cut Nominal Wages in a Deflationary Environment? *Explorations in Economic History*, 47(1):112–125. doi:10.1016/j.eeh.2009.06.002.

Shin, Y., Pesaran, M. H., and Smith, R. P. (1998). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Edinburgh School of Economics Discussion Paper Series No. 16.*

Šíma, J. (2002). Deflace - definiční znak zdravé ekonomiky. *Finance a úvěr*, 52(10):539–549.

Smith, G. W. (2006). The Spectre of Deflation: A Review of Empirical Evidence. *Canadian Journal of Economics/Revue canadienne d'economique*, 39(4):1041–1072. doi:10.1111/j.1540-5982.2006.00381.x.

Smits, J. P., Woltjer, P. J., and Ma, D. (2009). A Dataset on Comparative Historical National Accounts, ca. 1870–1950: A Time Series Perspective. http://www.rug.nl/research/ggdc/data/historical-national-accounts Retrieved on October 15, 2009.

Swiss National Bank (2018). Monetary Aggregates. https://data.snb.ch/en/topics/snb#!/cube/snbmonagg Retrieved on April 22, 2018.

Thornton, M. (2003). Apoplithorismosphobia. *The Quarterly Journal of Austrian Economics*, 6(4):5–18. doi:10.1007/s12113-003-1001-7.

Tobin, J. (1975). Keynesian Models of Recession and Depression. *American Economic Review*, 65(2):195–202.

Tobin, J. (1993). Price Flexibility and Output Stability: An Old Keynesian View. *Journal of Economic Perspectives*, 7(1):45–65. doi:10.1257/jep.7.1.45.

White, W. R. (2006). Is Price Stability Enough? *BIS Working Paper 205*.

Wooldridge, J. M. (2002). *Econometric Analysis of Cross Section and Panel Data.* Cambridge, Massachusetts: MIT Press. doi:10.1007/s00712-003-0589-6.

World Bank (2017). World Bank Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators Retrieved on September 10, 2017.

Appendix A

Changes and Replies to Comments

A.1 Comments from the PhD Committee

Below I list all comments from the PhD Committee as received by e-mail on December 20, 2017, and I provide replies to each of them. The replies are based on the written comments as well as on further discussions that I have had with members of the Committee.

Overall, I have reworked the thesis substantially in terms of data, methods and interpretation. I believe that it now addresses all of the comments raised.

Comments to Chapter Three

1. The quantity theory of money implies a long-term relationship between GDP, price level and money supply. Why the money supply is not included among the variables? Does the omitted variable bias arise or not? Please verify.

   Reply: I have added money supply as an additional variable in all regressions throughout the macroeconomic Chapter 3. Importantly, there is a new section (Section 2.5) that summarizes types of deflation within the DAS-DAD paradigm and explains how to address the issue empirically (i.e., discusses control variables). The addition of money supply as a demand factor is accompanied by the addition of oil price as a supply factor. Further new discussion of how to treat them as endogenous or exogenous in VECM's is in the 'Methods' section (Section 3.4.1).

   Overall, the addition of these variables did not change materially the main result that generally there does not seem to be positive impact of inflation on growth, as evidenced by VECM, ARDL and panel models. However, the inclusion of money supply may explain a certain difference between the present results and those of several studies which did not use control variables (I discuss this in Section 3.4.6). Including money supply and the oil price yields a slightly negative link between inflation and growth in some of the specifications where other studies reported zero or positive link. There is one exception: in the Great Depression, even the addition of money supply growth did not change the statistical and economic significance of the positive coefficient estimates on inflation. (Addition of money supply growth does make the coefficients somewhat smaller, but they still remain sizable.)

2. To what extent the main results can be influenced by endogeneity? Please provide rigorous discussion on possible endogeneity, its treatment, and influence on interpretation of the results.

   Reply: Based on a discussion with Dr Jaromír Baxa in April 2018, this comment was supposed to concern Chapter 4 instead of Chapter 3. As a result, I discuss it in the next

section.

3. Impulse response functions on pages 27, 29 a 42 do not present the respective confidence intervals. However without them, it is not possible to evaluate significance of the results.

   Reply: The reason why the impulse response function in the first version of the thesis were without confidence intervals is that the EViews software does not provide them for VECM's (while it does provide them for VAR's). In other words, the impulse response functions in *levels* are without confidence interval although impulse response function in differences of variables are with them. I have encountered similar difficulties with softwares Gretl and Stata, where e.g. for Stata the package for panel VECM (as opposed to time-series VECM) is a non-public package which I have not managed to obtain.

   As a result, to address the problem, instead of providing VECM impulse response functions, I now provide impulse response functions of the corresponding unrestricted VAR's which do have the confidence intervals. I have checked that the regression results of VECM's are very similar to the corresponding unrestricted VAR's, so that the impulse response functions from VAR's represent very closely those from the VECM's. The additional advantage is that VAR impulse response functions show reactions of differences ('dlogs') to differences, which better fits the focus of this thesis on inflation and growth rather than price level and GDP level.

4. The methodology section in Ch. 3 includes the ARDL model. Why the results from the ARDL model are not present in the main text?

   Reply: The ARDL model was originally applied only to the case of the Great Depression due to its length (only 6 years 1929–1934), where the VAR/VECM is unsuitable. I have now extended the usage of ARDL and provide the estimates for all samples studied in Section 3.4.6.

5. In section 3.4.2, it is argued there is no response of output to prices. But the coefficient at $p_t - 1$ in the equation of output is negative and significant and the Granger causality test implies significant causal relationship from prices to output. The conclusion of no response of output to prices seems to be inconsistent with these results. Please clarify.

   Reply: The original statement was meant to signify that the economic magnitude of the effects is very small and this statement was probably too simplified and imprecise. I have now more carefully described the difference between Granger causality and other results.

6. Other results in Chapter 3 seem to suffer by this inconsistency as well.

   Reply: The same applies as in the previous comment.

7. Table 3.12 – It seems that the results are based on a sample with just 24 observations. Apparently, this is too little just for OLS and for VECM for sure. Why not using data with higher frequency than annual? For the period of 1990 to 2015 in Japan those data shall be available.

   Reply: The annual data were probably unsuitable due to their low number and the section on Japan (Section 3.4.5) now uses quarterly data on real GDP, prices, money supply and

oil prices from 1Q 1990 to 4Q 2015. Unfortunately, real consumption was not available on a quarterly basis (only starting from 1995), so it is now excluded from the sample. All data is entered into the VECM in a seasonally-adjusted form.

8. The conclusions include "There is no evidence in the full-sample that deflation is harmful for growth." This seems to be an overstatement. The analysis did not say anything about potential nonlinearity between inflation and output indicating different relationship with inflation below zero (or below another threshold). This shall be clarified as well.

   Reply: The conclusions of the whole thesis and within each chapter are now more careful and discuss possible caveats. In addition, I have inspected the possibility of a different link between output growth and inflation when inflation is restricted to be only under zero (Section 3.4.6 with ARDL and panel FE). They do not point to the possibility that the link between inflation and output growth has been significantly different when inflation dropped below zero. Still, I discuss why these conclusions may not be without their problems. This should at least partially address the non-linearity issue.

9. What is the value added in comparison to the existing study Borio, C. E., Erdem, M., Filardo, A. J., & Hofmann, B. (2015). The costs of deflations: a historical perspective and Bordo, M., & Filardo, A. (2005). Deflation and monetary policy in a historical perspective: Remembering the past or being condemned to repeat it? Economic Policy, 20(44), 800 – 844. How do the interpretations differ and why?

   Reply: The focus of the two mentioned articles is different from the focus of this thesis. Bordo and Filardo (2005) mainly provide statistics such as deflation frequency, deflation persistence (measured by autoregressive coefficients), years of CPI and GDP peaks and troughs, determinants of inflation, and discuss historical episodes of deflation. However, they do not primarily investigate the effect of inflation or deflation on output growth through regressions. Borio et al. (2015), in contrast, do investigate the effect of inflation and deflation on output growth, but control mainly for measures of financial excesses (house prices, asset prices, debt, deviation of credit from trend). The focus of the present text is controlling for both demand and supply factors and applying a range of methods (VAR/VECM, ARDL, fixed effects). (The motivation for using the controls, based on current literature, is now described in Subsection 2.5).

   Namely, the differences and improvements of the present macroeconomic part over Borio et al. (2015) and Bordo and Filardo (2005) are:

   (a) Control variables: neither of the two mentioned studies (nor any other that I am aware of) has an explicit supply-side variable which I include here (oil prices 1861–2015) and only one (Borio et al., 2015) has a demand-side control variable (credit-to GDP).

   (b) Variables of economic activity: Both studies only have real GDP as the variable of interest on which to judge the effects of inflation or deflation. I have included real consumption, which has become available only recently as long-run historical series and which the mentioned studies did not include.

(c) Form of data: Borio et al. (2015) either run a regression only with annual contemporaneous values (without lags), or rely on up to 5-year average growth rates of prices, GDP and other variables. This approach may be too restrictive as it does not allow to see possible lagged responses. In the present work, these are allowed. Bordo and Filardo (2005) do not report regressions with output growth as dependent variable at all.

(d) Equation system: The VAR/VECM framework in the present text allows for feedbacks among the endogenous variables, which is missing in Borio et al. (2015). Bordo and Filardo (2005) apparently ran a VAR with Blanchard-Quah methodology for auxiliary purposes, but they do not report the results or impulse response functions.

(e) Convergence: Both mentioned studies include heterogeneous countries based on their level economic development, but do not account for the potential effect of convergence on prices and output. The present approach also takes this into account.

(f) Non-linearity: The present analysis allows for a estimation with inflation only under zero, which is absent in Bordo and Filardo (2005).

(g) Estimation: The present thesis uses both OLS estimation (in VAR/VECM) and Pooled Mean Estimator (in ARDL), which is absent in the two mentioned studies.

The comparison of the results of this thesis with the other important pieces of literature including Borio et al. (2015) is now discussed extensively in Section 3.4.6.

10. Make it clear in the thesis that the absence of an observed link between deflation and growth is consistent with standard macroeconomic models. If central banks successfully prevent the formation of deflation expectations, random episodes of deflation have no effect on economic performance. This should be stressed in the introduction and conclusion of the thesis.

    Reply: I have added paragraphs in the Introduction and Conclusion (Chapters 1 and 6) where I make the qualification that the nature of data and the results of this thesis may not be evidence against those deflation-recession arguments which are based more on expectations of deflation than deflation itself. I believe this is an important point and I have also added an extended discussion on expectations (Section 2.3.3.2) where I discuss trade-offs of using data on actual deflation versus deflation expectations.

11. Consequently, the thesis should refrain from making any policy recommendations ('good' inflation, 'bad' inflation), either implicitly or explicitly. The author claims that he makes no implications, yet the thesis is full of policy discussions. Note that these implications can be present if you change your specification to examine the link between growth and medium-term inflation expectations.

    Reply: The overall focus of the thesis has now been explicitly changed. I outline in the Introduction and reiterate in the Conclusion that factors such as (i) expectations and (ii) usage of sectoral data in Chapter 4 make the thesis much more theory-oriented than policy-oriented. Policy recommendations are not made. An extended discussion of expectations has been added (Section 2.3.3.2).

12. Generally, using data dominated by the golden standard period, where the majority of the deflation periods was driven by opposite implication (the output growths causes deflation), and making conclusions for the current period is disputatious. Author should discuss this and test for the structural breaks related to the abandonment of the golden standard. At least for some part of the sample the author should test for supply side effects (e.g. using oil prices as explanatory variable). In the "policy implication" part author should discuss, why the reactions of the world leading monetary policy authorities (FED, BoE, ECB) during the recent great recession, that were mainly motivated by fear of deflation, seem to be adequate from the ex post view and why the warnings from the "monetarists" from this period were not confirmed by data (warnings about galloping inflation).

    Reply:

    This comment has several points and I address them one by one:

    (a) I have added the oil price as variable to control for supply-side effects. It is now part of all regression results in the macroeconomic Chapter 3.

    (b) To account for a potential structural break caused by the change of the monetary system, the sample is split into the classical gold standard and a post-gold standard period (the split is done country by country based on the year when it left the classical gold standard). Results are reported separately. I also point out in the Summary of the macroeconomic part that results from the full sample cannot be automatically extrapolated to the present.

    (c) The interpretation of results is now more careful, more theory-oriented and without policy recommendations. As regards the reactions of the major monetary authorities to the Great Recession and warnings by some about inflation risks, the present thesis does not analyze the Great Recession 2008-09 as a separate subsample as it does in case of the Great Depression or contemporary Japan. The main reason is that the Great Recession was very short and most often constituted only 1 year of annual deflation. Given a long data set with annual data, this episode is too short to work with separately. As a result, I do not draw any conclusions from the whole data set or other subsamples for this episode.

13. For the cross country panel (e.g figures 3.7 on pages 38−39) I see problem with heterogeneity of the data included as far as the level of the economic development concerned—sample mixes "developed countries" with those that are converging. Analysis should thus control for the relative level of the GDP.

    Reply: To account for this, I have added GDP per capita in USD (in logs), similarly to a recent study by Eichengreen (2016). It is now in most regressions, except that for modern Japan (only one country over 25 years) and those in the ARDL framework (for computational reasons). The VECM's and fixed effects all have this variable. I also note that after leaving out observations with inflation rates outside the interval (-20%, +20%), a majority of observations for Argentina, Brazil and Chile drop out. In addition, since the Pooled Mean Group estimator takes estimates country by country, I had to leave out

the remaining observations for these countries completely since they were insufficient for estimation. Therefore, the convergence issue should be now addressed well overall.

14. Underlying data include surprisingly high share of datapoint with exactly zero inflation (3.2% of all observations—see table 3.2 on page 22). Is this correct?

    Reply: Yes, it is correct and it is explained in Footnote 5. The reason is that the original data source is in the form of a price index in whole numbers (integers). As a result, when the price index shows two identical whole numbers in a row, the resulting inflation is 0%. This issue concerns mainly the data sources on the old, 19th-century data, not modern-day data.

15. Author should comment and possibly test for the role of the inflation expectations in the deflation periods.

    Reply: As discussed in Comment 10, I recognize that the issue of expectations is an important one and was not discussed enough in the original version of the thesis. Extending the thesis to include data on expectations would probably go too far beyond its scope and would severely restrict the current data sets. However, I have now devoted more space to a discussion of the role of inflation expectations in Section 2.3.3.2 and I now also state in the Introduction and Conclusion (Chapters 1 and 6) that inflation expectations are one of the limitations of the work, although they may be partially covered by the inclusion of lagged inflation in regressions in the macroeconomic chapter.

Comments to Chapters Four and Five

Item 2 shifted from the previous section:

To what extent the main results can be influenced by endogeneity? Please provide rigorous discussion on possible endogeneity, its treatment, and influence on interpretation of the results.

Reply: I have substantially changed Chapter 4 to account for possible endogeneity of the price variable in modeling its influence on output growth. Within the section on panel data (Section 4.6) I have added Subsection 4.6.1 devoted to the problem of endogeneity and its econometric solution. In this subsection, I lay out the simultaneity problem of supply and demand equations and describe which instrumental variables are available and which ones I use. These changes are then reflected in the section with results (Subsection 4.6.2) where I present a new model and use 2SLS and GMM to address endogeneity.

Compared to the first version of the thesis, the results (coefficient estimates on price growth) do not change in sign, which stays negative in most cases, but rather in the absolute value of the coefficient which decreases. These changes, however, are not only due to tackling of the endogeneity problem but also due to an overall change of the model where I now estimate a demand equation (which was not previously the case) and include control variables for nominal demand such as money and credit.

I also note that the simultaneity problem discussed with members of the PhD Committee does not affect the cross-section regression of time averages in Section 4.5 (before the

panel data) where each observation represents one sector of the economy and so the goal is not to estimate a demand or supply equation for any sector. Therefore, I did not change the method in this Section, although I extended it in other ways.

Finally, I have not changed the non-parametric estimation in the last Chapter 5 on productivity (efficiency) and prices since, unlike Chapter 4, there is neither estimation of a demand or supply curve nor direct usage of quantities produced.

I have made fundamental changes which address all the three following questions, so I answer them together:

1. The sector-level analysis lacks proper theoretical underpinning. No theory used by central banks links sector-level deflation to macroeconomic recession. Either derive in a rigorous theoretical framework that there should be a link between sector-specific price development and monetary policy, or change the estimation framework to exploit a different feature of your data set.

2. Furthermore, the analysis is not backed by solid literature review on determinants of production and value added across firms. Such literature review can provide credibility to your analysis.

3. An appealing feature to investigate would be the formation of prices at the sector level, controlling for wages and other important characteristics.

   Reply: I have made two key changes to Chapter 4 which connect it better with the previous macroeconomic chapter and with the overall goal of the thesis. First, I have narrowed and better specified the goal of the chapter, which is to look for a link between price growth and output growth *after* controlling for demand and supply factors—i.e., to look for a sector deflation-recession link on top of those produced by changes in production costs or nominal demand. This directly follows the same task in the macroeconomic chapter, but uses a different type of data and different control variables. To provide reasoning for the move to sector data, I have added a new and extensive Section 4.2 ('Moving Closer to Microeconomics: Possibilities and Limitations') at the beginning of the chapter where I discuss why deflation-recession theories could be testable on disaggregated data, what pieces of literature have already moved in this direction and what are the benefits and costs of using this approach. Also, it is now stressed repeatedly throughout the chapter that it has rather little relevance for policy while it has more relevance for theory. I now devote a special part to this in Section 4.2.3.

   Second, in line with the narrowed goals of the chapter, the main estimation part of the chapter (Panel Data – Section 4.6) now concentrates on estimating effects of price growth on growth of *demand*. Therefore, the regressions with features of a production function which were part of the first version of the thesis are no longer present. This answers the second question above.

   Finally, there is now an extended role of formation of prices. To estimate the demand equation, I instrument output prices with prices of intermediate inputs (Section 4.6, 'Panel Data') since these satisfy best the inclusion and exclusion restrictions for instruments. As

I explain in this section, wages do not satisfy well these restrictions, which is why they are not used. This answers the third question above.

4. The interpretation seems to go too far. To what extent are the results affected by the fact the Czech Republic is an open economy with extremely high share of foreign trade, long-term appreciation of the nominal exchange rate and presumably high share of transactions in foreign currencies? Please discuss and verify that the results hold even if sensitivity tests are conducted.

   Reply: I have addressed this problem by a major extension of data and by tests of sensitivity. The openness of the Czech economy is now discussed in the section on Data (Section 4.3). To address this issue, I have added sector data from Japan and the United States (large and relatively closed economies) to the analysis and I have also split the Czech sample into goods-producing and service-providing sectors, as the openness affects mainly the production of goods. These checks are presented in the Results section (Subsection 4.6.2). It turns out that the results for the Czech Republic are robust to the split between goods and services and that the Japanese economy yields very similar results. The sample for the United States gives less significant results overall, but not opposite results in terms of the effect of price growth on output growth. Also, interpretations are now more careful overall.

5. Generally the shift from the micro deflations to macro level is complicated as even the sectors that have high share on the overall value added (e.g. automotive industry) need not have such high share on the inflation index itself. Moreover, the analysis does not much to say to general inflation generation but rather has implication for the output price creation of different firms. The interpretations from the analysis should be thus much more cautious.

   Reply: The introduction as well as the interpretation of results now takes this into account and is more careful. In the newly added Section 4.2 ('Moving Closer to Microeconomics: Possibilities and Limitations'), this is extensively discussed and there is now specifically a part in which we stress that we see the results as more relevant for theory than for policy. This is also reiterated at the end of the chapter (Interpretations and Discussion, Section 4.7, and Summary 4.8).

6. On the micro data the link between deflation and production growth is rather than macroeconomic phenomenon the manifestation of the positive productivity shocks. Analysis should control for these shocks as well as for the supply side shocks (e.g. changes of oil prices).

   Reply: The estimation of the effect of price growth on output growth now uses an instrument which is the growth in price of intermediate inputs. This is a variable that theoretically captures at least a part of supply-side shocks and satisfies econometric requirements for an instrument. Productivity shocks, though available, are strongly correlated with output and therefore cannot serve as an instrument in the estimation. This is why they are not used in Chapter 4. However, productivity is addressed in the final Chapter 5 where it is modeled as efficiency and analyzed using tools of efficiency analysis.

A.2 Comments from Opponents

Below I list comments and suggestions from opponents' reports on the thesis. In cases where the comments were not itemized in the opponent's report, I provide them with numbers and reply to each of them.

Prof. Joseph T. Salerno

Minor comments from the addendum to opponent's report:

1. p. 10: The author distinguishes between "extensive" and "intensive" economic growth. The former is described as the effect of an increase in the "number or amount of the factors of production"; the latter, as an effect of "investment [that] increases factors' productivity." Intensive growth increases factor productivity thus lowering "the costs of production per unit of output." This distinction is confusing. For let us assume that extensive growth results from an increase in the quantity of capital goods ("produced factors of production") rather than in the quantity of the "original factors of production," that is, labor and natural resources. In contrast to spontaneous growth in population or the fortuitous discovery of new sources of minerals, forests, or arable land, the increase in the stock of capital goods requires capital investment. But then how is extensive growth resulting from the increase in labor productivity caused by investment in additional capital goods to be distinguished from intensive growth, since they both are initiated by investment and both lower per unit product costs. Also not all intensive growth requires additional investment. For example there are organizational and technological changes that may increase total factor productivity without requiring additional investment.

   I suggest that the author explicitly define extensive growth as caused exclusively by an increase in the quantity of original factors of production, labor and natural resources. Intensive growth would then be defined as growth due to investment in capital goods that raises labor productivity or due to autonomous technological or organizational innovations that raise total factor productivity. Redefined in this manner, the distinguishing characteristic of intensive growth would be an increase in productivity of the original factors. Extensive growth, in contrast, would be marked by a decline in the productivity of the original factors as the ratio of capital to both labor and natural resources declines. The opposite changes in the productivity of the original factors would be the bright line separating intensive from extensive growth.

   Reply: I find this remark very useful as my original distinction between intensive and extensive growth was imprecise. I have rewritten the respective part of Section 2.3.2.1 and I now use the suggested distinction.

2. p. 33: This is most likely a typo. The author is here discussing the fact that in his study, the only evidence he found of a link between deflation and depression was the episode of the Great Depression. He then cites for support the study by Bordo, Lane and Redish who "note that the aggregate supply curve was probably much steeper during the Great Depression than during the classical gold standard period, which explains why in the

classical gold standard 'negative demand shocks did not have much of a contractionary bite.'" I believe the author means to say here that the AS curve during the GD was much flatter than during the CGS. For a given shift to the left in the AD curve, Y would fall much more and P much less along a flatter than a steeper AS curve.

Reply: I thank for pointing out the typo—it was meant to be 'flatter'. However, due to space constraints the part was redone and this particular reference left out.

3. p. 76: Another typo, I believe. In discussing the results of his sectoral analysis of the link between productivity and deflation, the author writes: "Contrary to the prevailing view the sectors with deflation or below average deflation are those in rapid development, not those in decline." In this sentence, I think that the author meant to write "below average inflation," instead of "below average deflation."

   Reply: This was a typo, too, but the wording was completely rewritten so it does not appear there any more.

4. p. 77: The author writes: "If productivity growth is the reason for deflation, however, higher real interest rates are only a reflection of higher real incomes and higher real return on investment. In fact, economic theory expects the real interest rate to go up as a natural response to higher productivity."

   The first sentence involves a non sequitur and the second sentence is just not true. Assuming that factor productivity increases as a result of an improvement in technology or business organization, then it may be the case that the natural rate of return on investment in the production structure increases and that this is naturally reflected in an increase in the real rate of interest in the loanable funds market. However, technological or organizational change is not the only cause of growth in factor productivity. If a decline in social time preferences occurs the result will be an increase in saving that shifts the supply of loanable funds to the right and causes a fall in the loan interest rate, an increase in investment and the associated bidding up of the prices of capital goods relative to consumer goods. The end result of this process would be higher factor productivity and a decline in the real rate of return on investment and, therefore, a lower real interest rate.

   So, contrary to the author's claim above, economic theory does not expect that an increasing real rate of interest is a "natural response" to higher productivity in all cases. In fact in the case of falling time preferences and greater investment in the capital structure, the causal link goes from a lowering of the real interest rate to a rise in productivity. Even a mainstream macroeconomist using a standard loanable funds model would criticize the author's argument on these grounds.

   Furthermore even an improvement in technology may increase current real income sufficiently to induce consumers to alter their intertemporal preferences in favor of the future, increasing their saving and lowering the rate of return on investment and thus the interest rate on loans. In this case too, the natural response to higher factor productivity would be a lower real interest rate.

Now, I realize that the author is here summarizing the argument of George Selgin and that his paper is an empirical study, which does not intend to formulate original theoretical arguments in defense of deflation. Nonetheless, a flawed theoretical argument detracts from his empirical case.

Reply: Indeed, the first quoted sentence was just a summary of one of Selgin's (1999) arguments. The second sentence was rather meant to be a ceteris paribus argument based on Selgin—i.e., if productivity goes up and no preferences change in the society, then the real interest rate should go up because the real return on investment has gone up too. However, I acknowledge the problems with this reasoning and I have now highlighted this in two parts of the text (Sections 2.3.2.2 and 5.2).

Prof. Jörg Guido Hülsmann

1. Ad Chapter 2: It is forgivable that the list of references is not complete in this part of the thesis. For example, the author could have quoted C.H. Carroll's Organization of Debt into Currency as an important predecessor of Irving Fisher's 1933 article. It would also have been helpful to distinguish more systematically between reductions of the price-level, reductions of the money stock, and reductions of the money supply; but, again, neglecting these distinctions is forgivable in a work that is clearly focused on the empirical record of price-deflation.

   Reply: I appreciate the reference to Carroll's work (of which I was not aware) and I now briefly cite it in Footnote 6. As regards the distinctions between reductions of the price-level, money stock, etc., I briefly explain in Section 2.1 that I adhere to the currently used definition of deflation as reduction in the price level, although the original meaning was different. Since the thesis is an empirical one, I do not include more discussion on these distinctions even though they are theoretically important.

2. Ad Chapter 3: Going beyond these predecessors, he also discusses the important case of Japan after 1992. Here the introduction of control variables proves to be especially useful, as it turns out that the per-capita performance in Japan in that period was by and large the same as in Germany, France, and Italy, even though the annual price-inflation rate was about 2 percent higher in the latter countries as compared to Japan. Mgr Ryska might have spent a little more time presenting and analysing the ultimate data sources, as well as questions pertaining to data quality.

   Reply: The data and their sources are not presented in the main text in order to save space, but are presented in Appendices 3.A and 3.B to Chapter 3. I list a total of 9 different data sources for the macroeconomic variables and I believe that describing in detail the original data sources of these sources would take too much space with not so much value added for the reader. However, all of the listed sources are either impacted journal articles, books or well-known websites with historical datasets. As for data quality, I provide a short discussion in Footnote 6 where I mention a possible reason for the higher standard deviation of older (19th-century) data and the fact that some of the older data were estimated ex post rather than measured.

Dr. William White

1. The thesis makes reference to relevant references. I would only suggest that, in referring to Selgin's papers, he should note that Selgin refers to a huge pre-War literature debating whether increases in productivity, and therefore real wages, should more appropriately be driven by increases in wages or a decrease in prices.

   Reply: In Section 2.3.2.1 I have added a footnote on Selgin's coverage of this issue in his 1997 book.

2. First, and this is the focus of his empirical work, he noted the important influence (throughout history and at the sectoral level) of positive supply side shocks on reducing inflation. This is a 'good' deflation in which both real wages and profits can rise. Second, Ryska provides grounds for doubting the arguments often used to support the view that deflation can exacerbate downturns caused by negative demand shocks. For example, there seems little empirical evidence to support the view that falling prices are extrapolated into the future and spending postponed as a consequence. I would, however, have liked to see these two sets of arguments more clearly distinguished in the text.

   Reply: A similar issue was raised by the pre-defense committee in Comment 2 above, referring to potential endogeneity, and my reply is therein.

3. More broadly, Ryska might usefully have included a few paragraphs early in his text on the undesirable side effects of expansionary monetary policy. (...) Vastly inflated asset prices, financial markets without a capacity for price discovery, malinvestments of various sorts and other ills of a traditional "Austrian" sort could all be briefly mentioned.

   Reply: I believe that if I was to make such assessments, my empirical analysis would have to include variables such as asset prices and property prices or direct monetary-policy variables such as policy rates or central banks' balance sheets. My goal in the present work was to examine the link between price changes and output changes as such, not the association of the business cycle and deflation with asset prices, for instance. (The topic of asset prices and property prices is nicely covered by Borio et al., 2015.) Still, I mention malinvestments in describing Rothbard's account of the Great Depression in Section 3.4.4.

Minor comments:

1. p. 4, second last line. What were Hayek's thoughts on secondary depressions? To be resisted or not?

   Reply: His stance was, in my opinion, a little ambiguous. I have added a short discussion on this in Footnote 21.

2. p. 5, 2.3.1 Take care to ensure each argument is treated similarly; nature of the argument, criticism of the argument, then how each might be tested empirically.

   Reply: I have changed especially Section 2.3.1.1 so that it first has the nature of the argument and then opposing opinions.

3. p. 5, fourth last line. 'fixed' It is not just the problem of the ZLB. Keynes notes in the GT that long rates can fluctuate around the wrong level for 'decades at a time'.

   Reply: I have now emphasized in the text that the level does not have to be zero, but that the zero lower bound is a well-known case.

4. p. 6, fn3 Very nice point.

   Reply: I have moved this argument from the Footnote to the main text of Section 2.3.1.1.

5. p. 7 line 1. What is really at issue is the wage bill. If falling wages do not induce enough hiring, then AD falls anyway.

   Reply: I have added this point.

6. p. 7, ref to Seltzer The regime does matter. Ref to Keynes being right about the risks of the UK going back to the gold standard at too high a rate?

   Reply: I would prefer to leave the reference to Seltzer as it is now because it covers a relatively rich amount of data. That of course does not contradict the case with Keynes and his evaluation of the UK's return to the gold standard, but that is only one observation while Seltzer's study covers many cases.

7. p. 7, second last line. Say why AD drops. Note the contraction in supply helps limit the downward spiral. Note what happens when supply does not contract, as seems to be happening today with zombie banks and zombie companies (especially in China).

   Reply: I have explained in more detail the functioning in AD in AS in the given paragraph.

8. p. 7, Debt deflation more generally. There is a paradox in the literature. On the one hand, Fished emphasizes the effects of deflation on real liabilities. On the other hand, Patinkin focused on real assets and made the real balance effect the key to getting back to full employment. Go figure!

   Reply: Patinkin's (and Pigou's) real balances effect is an important point which was missing in my theoretical overview. I have now added their views both in Section 2.3.1.1 and in Section 2.3.1.3 where I contrast them with Fisher.

9. p. 8, middle 'Debt deflation clearly...' But what if the debtor cannot pay?

   Reply: I am thankful for this remark which I have now stressed more in Section 2.3.1.3 and mentioned in comparing Fisher with Pigou and Patinkin. I have also added Footnote 10 which emphasizes this problem in the discussion about redistribution of wealth between creditors and debtors.

10. p. 9 Top Distinguish between the signal getting through (monetary conditions do ease) and spenders responding to the signal. If easy money encourages bringing spending forward, then it only works for a while. Eventually tomorrow becomes today and it is payback time.

    Reply: I touch upon this problem already in Section 2.3.1.1 where I bring up the question whether deflation can postpone spending forever and, vice versa, whether inflation can bring all spending forward without impairing it severely in the future.

11. p. 9, bottom. I agree with Sanches, the 'shoe leather' problem is not big enough to worry about.

    Reply: I also personally agree with Sanches's assessment but I refrain from judging it in the text.

12. p. 10, fn 10 Do Friedman and Schwartz say anything about the costs of deflation?

    Reply: To my knowledge not in detail. They for example criticized the UK's sharp deflation in order to restore the gold standard in the 1920s at the pre-war parity (Friedman and Schwartz, 1963a, p. 41), which in their view caused an economic slump. But they did not elaborate on it much. Similarly, they wrote that economic adjustment is more difficult to deflation than to inflation (ibid, p. 283), but again without details. This is why I cite Friedman and Schwartz only when it comes to empirical observations, not theory.

13. p. 11, para re Selgin A rise in profits may raise the natural rate of interest but not necessarily the financial rate.

    Reply: That may well be the case, but for the sake of simple exposition of Selgin's argument I do not make this further distinction.

14. p. 13, para 2. Distinguish more clearly between the bad effects of deflation and the inability of monetary policy to lean against them.

    Reply: I haved emphasized this more in the given paragraph in Section 2.3.3.1.

15. p. 13 Fourth last line Could consumer and businesses have different expectations?

    Reply: One could argue that businesses may spend more time and resources to form expectations (especially rational expectations in the sense that they contain all available information). This could make their expectations more precise. However, I am not aware of a study that would deal with the difference in expectations between businesses and consumers, so I do not take up this issue in the text.

16. p. 14 Could your data set be broken down to distinguish between periods of accelerating inflation, decelerating inflation, and periods of deflation to allow a specific test of which are the most harmful to growth?

    Reply: Comparing disinflation with deflation is problematic because disinflation in fact describes the change of change of prices (i.e., the 2nd derivative of prices), while deflation, similarly to inflation, describes just the change (1st derivative). Strictly speaking, accelerating price change or decelerating price change may occur both in the inflation territory and the deflation territory. Therefore, I believe the link between disinflation and growth could be studied, but it would involve again taking specific territories (disinflation while inflation is above zero and disinflation while it is already below it, i.e deepening deflation). However, this would perhaps be too apart from my primary goal in this text, which is deflation as such.

17. p. 19 Limitations of current research. Focus more on the weaknesses of the studies that say deflation does weaken growth?

Reply: Two studies mentioned at this place are actually the two well-known ones that say that deflation weakens growth—Guerrero and Parker (2006) and Benhabib and Spiegel (2009).

18. p. 20, line 5. Would investment be better than the ratio? If income falls as much as investment, the ratio might not change at all (or certainly less). More generally sometimes you seem to use Investment as the control and at other times consumption. I got confused. Similarly, be more consistent in your use of prices and inflation. Sometimes you use the former when you mean the latter.

    Reply: The reason for the use of investment/output ratio was its availability. I was able to obtain this ratio from Jordà et al. (2017). However, real investment (which would methodically match real output and real consumption in the regressions) is not as available and cannot be computed from real output and from the investment/output ratio (what is missing is the price deflator for investment). Therefore, I used the investment/output ratio.

    However, now all the regressions have money supply, oil price and level of economic development as new control variables. These should be theoretically more important for controlling in shifts of demand and supply, as I now explain in Section 2.5.

19. p. 23 Last full para. 'A cautionary...' You are right. The Philips curve approach says output drives inflation, while the consensus also says that inflation (deflation) drives output. How to test the joint hypothesis?

    Reply: This is an important point and I have added Section 2.5 that discusses what is feasible for empirical research. In short, we can control for certain supply and demand shifts, which I now do in this work, but I am not sure if this two-ways relationship is testable. In fact, for example Mankiw (2001) argues that there does not necessarily need to be a clear opinion on what the direction of causation is. Rather, money supply affects both output growth and inflation. In any case, I believe the ambiguity of potential effects reinforces the case for the use of VAR/VECM framework which allows feedbacks.

20. p. 26 Table 3.6 I am struck by how little explanatory power this test indicates, but I suppose that is the whole point.

    Reply: The low *Adj.* R^2 is indeed a symbol of how little of output movements is explained by movements in prices. Other existing studies show similar fit.

21. p. 36 First para. Friedman and Bernanke say that policy error caused the Great Depression, not the previous credit bubble. When we look at busts in other countries, at other times, are we to believe that they were all the result of policy errors. It beggars belief.

    Reply: This is a logical question, but it deals more with particular cases of monetary policy decisions which I do not cover in the text.

22. p. 30 Top. Might refer to Governor Shirakawa's speeches. He also notes that if you calculate (could go in Table 3.14) the rate of growth of GDP per person of working age,

the Japanese have even outperformed the US. So Kuroda is taking huge risks in dealing with a non-problem.

Reply: I have two similar measures in Table 3.14, which are GDP per worker and per member of labour force, which I think illustrate well the same point. Elsewhere in Section 3.4.5 I mention an interesting paper on Japan by Baba et al. (2005), co-written by former Governor Shirokawa, which challenges the possibility of debt-deflation in Japan.

23. p. 50 Top. This is an obvious point. That said, like many obvious points, I had not in fact thought of it. A very powerful counter argument to Rogoff et al. Good for you.

    Reply: No changes made.

24. p. 62 Section 4.2 This repeats a lot of what you said before.

    Reply: The reason is that there are 3 empirical chapters in the thesis which logically follow each other, but still each can stand on its own. Chapter 3 (the macroeconomic one) follows the standard approach, but Chapters 4 and 5 are relatively novel in their approach and if the reader is interested in reading only one of these, he or she might need a 'bridge' from the standard macroeconomic approach to the sector approach. This is why I include brief overviews in these chapters (i.e., Sections 4.2 and 5.2).

25. p. 73 Bottom Say that the next chapter will do this.

    Reply: This mention is now at the end of Section 4.8.

26. p. 77 Section 5.2. Again, repeats earlier stuff.

    Reply: See Item 24.

27. p. 78 on Balassa-Samuelson. Do your results imply that BS does not apply in the Czech case? If so, does this conflict with other empirical work?

    Reply: I appreciate this remark and I have added a Subsection 5.2 describing the Balassa-Samuelson effect, Subsection 5.2 discussing how it complements the present analysis and finally a mention in Summary (Section 5.5). In our view, the results are not at odds with the Balassa-Samuelson effect; rather, it could be a complementary force.

A.3 Other Changes

Below I list further changes made in the thesis since pre-defense—i.e., other than those mentioned in the previous two sections.

1. I have moved Survey of Empirical Literature (now Section 2.4) from the macroeconomic Chapter 3 to Chapter 2. This regrouping now assembles all existing literature—both theoretical and empirical—in Chapter 2. This allows to better explain the goals of the present work at the end of this chapter.

2. I have extended Descriptive Statistics in the macroeconomic Chapter 3 by adding Subsection 3.3.2 with Table 3.5 and Figure 3.2. They show mean GDP growth under inflation

and deflation (together with t-tests) for 9 different historical subsamples (episodes) of interest. Especially Figure 3.2 is important, in my opinion, in visualizing different experiences with deflation throughout economic history.

3. I have moved the comparison of GDP growth under mild inflation and mild deflation under Descriptive Statistics, i.e. Section 3.3. Previously it was an independent section. The new approach is more systematic since this part compares GDP growth under 4 different inflation intervals and therefore is a logical follow-up on other descriptive statistics.

4. I have expanded Section 3.4.1 which describes the econometric methods used for macroeconomic analysis (VAR, VECM, ARDL, FE). The models and estimation methods are now described in more detail.