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MASTER THESIS

Endogeneity of Credit or Nominal Rigidities?

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

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Prague, May 19, 2010

Signature

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Abstract

This thesis presents a theoretical model which tries to explain causes of business cycles fluctuations and which has its roots in the Post Keynesian stream of economic thought. According to this model, investment shocks together with endogeneity of money causes business cycles fluctuations. This model is compared with existing New Keynesian models which assert that causes of business cycles fluctuations are monetary policy shocks together with various nominal and real rigidities. Author uses econometric techniques (impulse-response functions and forecast error variance decomposition) to investigate which phenomenon contributes more to business cycles fluctuations. Unfortunately, results do not enable to draw a straightforward conclusion. It seems that both phenomena play a certain role.

JEL Classification	E32, E37, E41
Keywords	endogeneity of money, nominal rigidities, business cycles, monetary economics

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Abstrakt

Práce prezentuje teoretický model, který se snaží vysvětlit příčiny hospodářských cyklů a který má základ v postkeynesiánské ekonomii. Podle tohoto modelu jsou příčinou hospodářských cyklů změny v investicích a endogenita peněz. Dále jsou studovány modely nové keynesiánské ekonomie, podle nichž jsou příčinou hospodářských cyklů změny úrokových měr způsobné monetární politikou spolu s nominálními a reálnými rigiditami. Autor dále využívá různé ekonometrické metody (impulse-response funkce a analýzu rozptylu), aby určil, které fenomén z výše jmenovaných způsobuje hospodářské cykly více. Na základě výsledků není bohužel možné učinit jednoznačné závěry. Nejspíš oba dva fenomény hrají určitou roli.

Klasifikace JEL	E32, E37, E41
Klíčová slova	endogenita peněz, nominální rigidity, hospodářské cykly, monetární ekonomie

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Acronyms

Teze diplomové práce

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Téma: Endogeneity of Credit or Nominal Rigidities?

A) Cíl práce

Cílem práce je zjistit, zda příčinou fluktuací hospodářského cyklu je spíše endogenita peněz či rigidita cen či mezd; jinými slovy je-li katalyzátorem recesí spíše finanční sektor či rigidity na trhu práce. Zvláštní pozornost bude věnována vztahu reálných a nominálních veličin.

B) Výzkumné otázky

- je katalyzátorem recesí spíše endogenita peněz či nominální rigidity?
- je hospodářský cyklus exogenní či endogenní proces?
- je tržní ekonomika inherentně stabilní či nestabilní?
- jsou peníze neutrální vůči reálné ekonomice či nikoliv?
- jakou roli hrál finanční sektor při propuknutí finanční krize?
- jak ovlivňuje fiskální resp. monetární politika volatilitu hospodářského cyklu?

C) Metoda zkoumání

V práci bude sledován následující postup. Bude sestrojen model hospodářského cyklu, který inkorporuje jednak endogenitu peněz, tak nominální rigidity; popřípadě budou sestaveny dva modely, přičemž jeden bude založen na endogenitě peněz a druhý na nominálních rigiditách.

Model založený na endogenitě peněz by měl být sestaven v duchu post-keynesiánské tradice. To znamená, že by měl popisovat hospodářský cyklus jako endogenní samo se udržující mechanismus a měl by být založen na interakci efektivní poptávky a měnové endogenity. Tento model se bude inspirovat články H. Minského, M. Jarlusica, M. Lavoaie či R. Goodwina, ale neměl by jejich modely explicitně kopírovat.

Model založený na nominálních rigiditách by měl reflektovat ekonomické myšlení nových keynesiánců. Hospodářský cyklus by měl být podle tohoto modelu spíše exogenní povahy, kdy nominální rigidity zesilují dopad exogenních šoků na reálnou ekonomiku. Měl být inspirovaný články P. Irelanda, T. Yuna, L. Christiana a dalších.

Dále bude následovat kalibrace modelu(ů) (tj. z výpočet hodnot klíčových parametrů modelu(ů)) a simulace modelových ekonomik. Následně bude testováno, který z jmenovaných fenoménů více přispívá k vysvětlení klíčových znaků hospodářského cyklu poválečných Spojených států; tj., který model vysvětluje data lépe. K tomuto účelu bude využita metoda vektorové autoregrese (VAR), což je způsob testování modelů v nové keynesiánské ekonomii, nebo metoda porovnání časových řad klíčových agregátů ekonomiky Spojených států s modelovými časovými řadami pomocí druhých výběrových momentů. Tato metoda se povětšinou využívá k testování RBC modelů.

Po vyhodnocení výsledků empirických testů budou vyřčena některá hospodářsko-politická doporučení.

D) Předpokládaná struktura práce

1. Úvod - přehled literatury, popis vývoje teorií hospodářských cyklů,
   - popis metodologie.
2. Konstrukce modelu(ů) - teoretické zdůvodnění endogenity peněz a nominálních rigidit,
   - odvození dynamických rovnic.
3. Kalibrace - výpočet hodnot klíčových parametrů.
4. Simulace modelu(ů).
5. Empirické testování - VAR nebo porovnání druhých výběrových momentů.
6. Závěr - vyhodnocení testů,
   - formulování hospodářsko - politických doporučení.

E) Literatura

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Podpis vedoucího diplomové práce Podpis autora

Chapter 1

Introduction

There exist many competing theories of business cycles, RBC theory, Monetarism, New Keynesian and Post Keynesian theories etc. This thesis is interested in the two last-mentioned theories and partly in the Monetarism. The research question is: What causes business cycles fluctuations? Investment shocks together with endogeneity of money or monetary policy shocks together with nominal rigidities?

To answer this question the Post Keynesian model which is based on effective demand and endogenous money is constructed in the section 2.2. This model enables to construct endogenously generated self sustaining business cycles. So this model presents market economy as inherently unstable.

The Post Keynesian model is confronted with New Keynesian models in the section 2.4, namely with the model presented by Christiano *et al.* (2005). This model embodies moderate amount of nominal and real rigidities and can serve as a benchmark. According to New Keynesian models, monetary policy shocks together with nominal or real rigidities can cause business cycles.

The section 3.1 contains estimated reduced-form VAR model and its analysis by means of impulse-response functions and forecast error variance decomposition. Such an analysis is appropriate to identify key business cycles facts. It enables to answer such questions as: Is money endogenous or exogenous? How does GDP and price level respond to various shocks? Etc.

The section 3.2 contains two estimated SVAR models and their analysis. These models are based on theoretical model from the section 2.2. The first model has horizontal supply of money (the Post Keynesian model) whilst the second one has vertical supply of money (the Monetarist model). The author is interested what model is able to fit business cycles data better.

Last but not least, the chapter 4 concludes achieved results.

Chapter 2

Theoretical models

2.1 Justification of the endogeneity of money

This section seeks to describe the Post Keynesian theory of money, its historical roots, development, motivations, characteristics etc. Author also tries to compare this theory with competing monetary theories (namely with Monetarist theories) and tries to explain why our contemporary market economies should evolve according to the Post Keynesian predictions.

2.1.1 Historical roots

The beginnings of the theory of endogenous money can be found in work of J. M. Keynes. However, they can be found neither in the *General Theory* nor in the *Treatise on Money*. That is why, endogeneity of money could not be included in textbook interpretation of Keynes‘ theory. Keynes came with the idea of the so called *monetary production economy* (see e.g. Kregel (1980)), which was spread by the Post Keynesian economists later on. Properties of the monetary production economy will be described bellow, as far as historical development of endogenous money theory is described.

The theory of endogenous money was not incorporated into the Post Keynesian economics until seventies. It was known mainly for its growth and distribution models until then. Only the rise of Friedman's Monetarism was an impulse for development of the Post Keynesian monetary theory - theory of endogenous money. Building of the theory of endogenous money was connected with names as Kaldor, Davidson, Moore and others. One can say that the endogeneity of money has been major topic of the Post Keynesian economics since seventies. Nowadays, this theory is adopted by other streams of economic

thought, namely by the New Keynesian economic. However, economics who belong to this stream conclude that the money supply endogeneity does not play so important role in generating business cycles fluctuations relative to nominal rigidities see Ireland (2003) and Yun (1996).

2.1.2 The Post Keynesian monetary theory

As pointed out above, the Post Keynesian monetary theory differs from the standard Neoclassical one. The Post Keynesians stem from the monetary production economy, i.e. no producing is possible without money. Money is in this framework as any other input of production (as labor and capital). Investing entrepreneur must ensure financial resources in advance, before installation of capital equipment. Entrepreneur must go into debt and ask a bank for credit or at least for renewal of existing credit contracts. This is called the *financial motive* for holding money. It was originally described by J. M. Keynes, unfortunately not in the General Theory. If bank is willing to provide additional flow of credit, entrepreneur can realize investment decision and consequently raise nominal income. This is the so called *income generating-finance process*. If investing entrepreneur has foreseen the level of aggregate demand correctly (i.e. within some margin of safety), there should not be any problem to fulfill payment commitments. If not, financial crisis could occur depending on whether entrepreneur is able to refinance debt. Initiating mechanism of financial crises was described in details by Minsky (1982; 1986).

Clearly, the Post Keynesian view is very different from the standard Neoclassical one. In standard general equilibrium setup money is introduced as injection once output is determined. This injection is implemented by monetary authority, which is able do allow whatever money growth it wants. However, this does not reflect reality according to the Post Keynesians. The way the Post Keynesians see is that money neither falls like manna from haven nor is dropped from helicopter. This is because of two reasons.

Firstly, monetary authority can sustain target money growth only at the costs of disrupting financial markets according to Lavoie (1984). If a financial turmoil occurs and portfolios of financial and nonfinancial corporations are hungry for liquid liabilities, then sustaining of target monetary rule is consistent only with rejection of calls for lender of last resort actions of monetary authority and risking of domino effects. Moreover, absence of actions to accommodate liquidity crisis would induce rise of nonbanking financing, rise of

credit multiplier and income velocity of money and consequently loss of any control over monetary aggregates.

Secondly, central bank is not the only player, which can issue new money. Commercial banks can raise existing stock of money by providing additional flow of credit. If they are able to act independently of central bank, then monetary aggregates need not evolve according to wishes of central bank. In such a case money supply will not be vertical, but will be more less flat (see the next section).

2.1.3 Two types of endogeneity

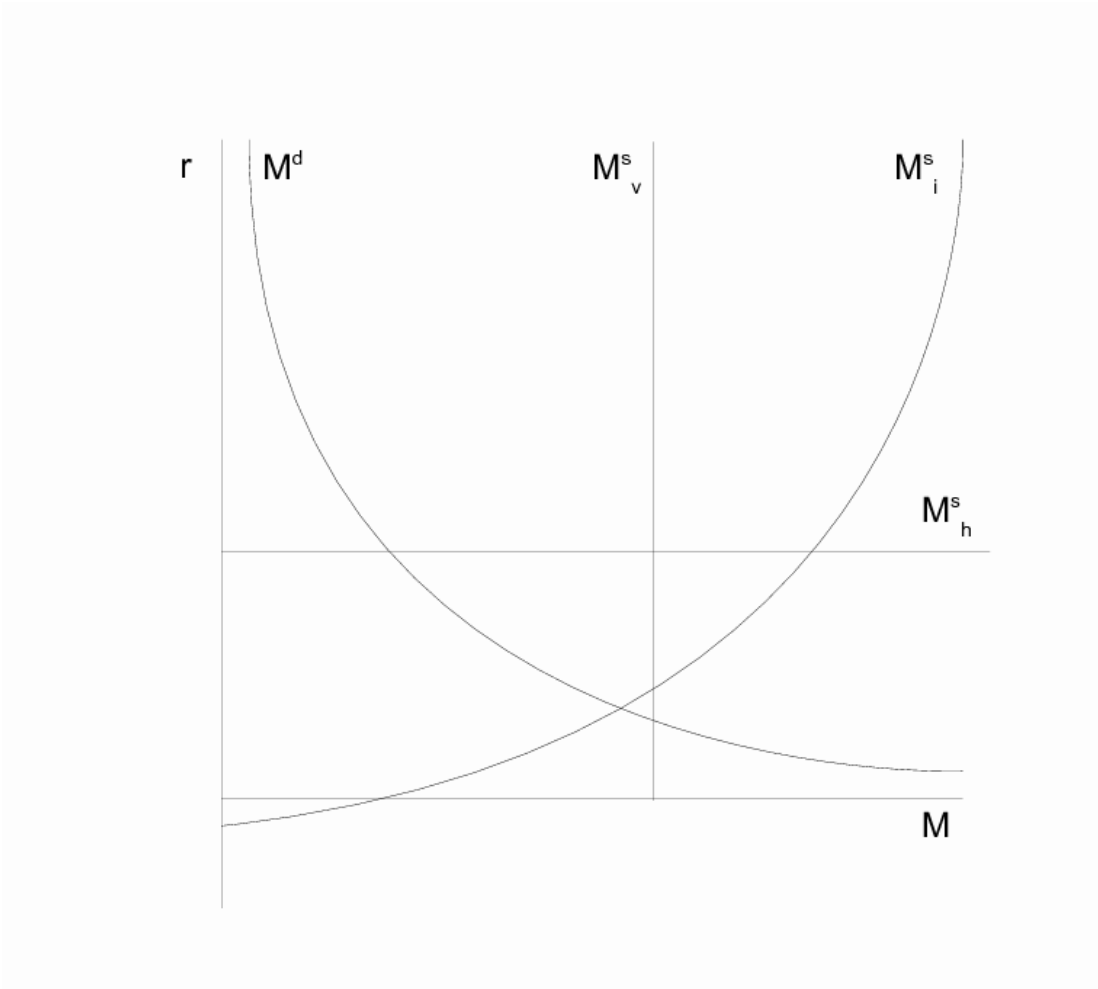
There are some differences in the view on the endogeneity of money even within the Post Keynesian stream. These differences can be most easily demonstrated by the figure 2.1.

The money supply curve M_v^S represents view of Monetarists. According to this view monetary authority can fully control amount of money in economy (or money growth in dynamic context). This is demonstrated by the vertical money supply curve.

The money supply curve M_h^S represents the so called horizontalist approach towards the endogeneity of money. Leading economists who belong to this sub stream of the Post Keynesian economics are Nicholas Kaldor and Basil Moore. They contend that monetary authority can sustain desired amount of money only through interest rates (if the demand for money is known), so the control over the money stock is indirect. Monetary authority acts defensively. It supplies such an amount of reserves that is necessary for smooth functioning of financial market and commercial banks provide the amount of credit according to needs of entrepreneurs. Banking system only sets costs of borrowing. This fact can be illustrated by the horizontal money supply curve. This approach is contraposition of the Monetarist view. Money is absolutely endogenous and interest rate exogenous while in the Monetarism holds the reverse. For more detailed description of the horizontalism see Lavoie (1984).

Last but not least, the money supply curve M_i^S represents a broader view on monetary policy than two approaches discussed before. For example (Dow & Rodriguez-Fuentes 1998, page 1) say that: "An endogenous supply in this more fundamental sense means that monetary policy, using whatever instrument, does not determine the money stock but is only one of its multiple determinants."

Figure 2.1: Money supply



Economists who advocate this approach assert that monetary authority can not determine money stock anyhow, neither directly nor indirectly through interest rate manipulations. The monetary policy does not rely only on traditional instruments as open market operations and it involves financial market regulation and supervision as well. They simply say that banks do not fully accommodate demand for credits and accommodation is partial. It means that there are limits on credit expansion of banks what can be depicted by convex shape of M_i^S curve.

"Monetary policy does matter even if money is endogenous" (Dow & Rodriguez-Fuentes 1998, p. 8). Monetary policy actions represent shifts of money supply curve M_i^S.

2.2 The Post Keynesian model

The following notation will be used in the Post Keynesian model: j_t denotes value of sequence $\{j_t\}_{t=0}^{+\infty}$ at time t whilst j (short-cut) without subscript t denotes sequence $\{j_t)_{t=0}^{+\infty}$. It will be explicitly mentioned, if some variable is constant over time.

The Post Keynesian model of monetary economy consists of equations (2.1), (2.5), (2.6), (2.7) and (2.8). This model is a slight modification of models in Tobin (1970) and Jarlusic (1989). Their models are characterized by multiplier determination of national product and by modeling of financial sector by means of supply of and demand for money.

The real level of national product Y is determined by the following multiplier relation

$$Y_t = m_t I_t, \tag{2.1}$$

where m is multiplier and I is the real value of gross investment. The subscript t indicates that multiplier is not time invariant in contrast to Samuelson‘s income-expenditure model, where the value of multiplier is constant over time. This difference is explained bellow.

The value of multiplier m can be determined from investment savings identity

$$I_t(r_t) = s_w W_t + s_p P_t, \tag{2.2}$$

where W is the real value of wage income and P the real value of capital income, or profits in the Post Keynesian terminology, and s_w and s_p, $s_p > s_w \geq 0$ are corresponding propensities to save. We will assume for the sake of simplicity that propensities are constant over time.

It is appropriate to spend some time to explain meaning of the shape of saving function (2.2). The equation (2.2) is always satisfied ex-post, since it is identity. However, there is no reason, why such an equation should be satisfied ex-ante, since investment decisions are made by management of firms while saving decisions are made by households and shareholders. If e.g. ex-ante investment is higher than ex-ante savings, it causes rise in price level relative to wage rate what induces rise of corporate profits and rise in savings. Therefore, one can say that the equation (2.2) is satisfied ex-ante as well, i.e. investment creates its own savings. Rise in interest rate does not cause increase in savings

directly, since interest rate clears money market in this model (see later) not goods market.

The Post Keynesian theory is absolutely different world in comparison with the standard Neoclassical theory. The Post Keynesian theory must satisfy namely the following conditions: reality of assumptions; methodological collectivism; organicism and stress on historical time. For the more detailed description of the Post Keynesian methodology see e.g. Lavoie (1992). The shape of the saving function (2.2) reflects methodological collectivism. It is not derived from individual decisions of households as in the case of the Neoclassical economics. It is based on collective choice. The society is divided into two income groups: workers who receive wage income and let us say shareholders who receive profits. The saving decisions are homogenous within income groups but heterogeneous across income groups. The saving decision is relatively simple in this model. Each income group saves a constant fraction of its income. However, the saving decisions can be much more complicated, e.g. Fazi & Salvadori (1985) use the following saving function

$$S_t = F\left(P_{wt}, W_t\right) + G\left(P_{ct}\right),$$

where F and G are general functions, P_{wt} and P_{ct} are profits earned by workers and "capitalists"at time t. More recently, Salvadori (1991) augmented the saving function as follows

$$S_t = F\left(P_{wt}, W_t, K_{wt}\right) + G\left(P_{ct}, K_{ct}\right),$$

where K_{wt} and K_{ct} represent workers' and "capitalists'"wealth at time t.

The saving function (2.2) is related to the Post Keynesian theory of distribution. The Post Keynesian economics does not rely on Neoclassical micro foundations in contrast to the Neo Keynesian economics and tries to develop its own theory of distribution which is not based on marginal productivity. In other words, the Post Keynesian economics wants to complete the Keynesian revolution. The Post Keynesian theory of distribution was firstly proposed by Kaldor (1956). He asserts that income is distributed so that it would be created enough savings to cover desired (planed) investment. This can be illustrated by the following equation

$$\frac{P_t}{Y_t} = \frac{1}{s_p - s_w}\frac{I_t}{Y_t} - \frac{s_w}{s_p - s_w}.$$

This relation can be obtained by appropriate manipulations of the equation (2.2), where $\frac{P_t}{Y_t}$ is independent variable and $\frac{I_t}{Y_t}$ dependent variable and causality runs from $\frac{I_t}{Y_t}$ to $\frac{P_t}{Y_t}$. So the distribution of income is determined by investment decisions of entrepreneurs according to this theory.

This approach was subject to criticism of Samuelson & Modigliani (1966). They connected the problem of distribution of income with technological aspects and their paper initiated the era known as Cambridge (UK) vs. Cambridge (US) controversy.

By substituting (2.1) into (2.2) one can explicitly express the value of multiplier

$$\begin{aligned} m_t &= \frac{Y_t}{s_w W_t + s_p P_t} \\ &= \frac{1}{s_w \frac{W_t}{Y_t} + s_p \frac{P_t}{Y_t}} \end{aligned} \tag{2.3}$$

Now it is clear why m is not time invariant. The value of multiplier depends upon the distribution of income between wages and profits within the Post Keynesian framework. Since the distribution of income is not constant over time, m can not be time invariant in this model.

Let us denote the wage income share ω and capital income share $1-\omega$, then by plugging (2.3) into (2.1) one can express the value of output as follows

$$Y_t = \frac{1}{s_w \omega_t + s_p(1-\omega_t)} I_t. \tag{2.4}$$

Let us express the investment function.

$$I_t(r_t) = A_t r_t^{\lambda} Y_t^{\chi}, \tag{2.5}$$

where the constant $\lambda < 0$ indicates negative relationship between investment and interest rate. Real interest rate determines the threshold for profitable investment. Only projects with the rate of return higher than real interest rate will be realized. Therefore, investment is decreasing function of real interest rate.

The term A can be interpreted in the Post Keynesian way as animal spirits of entrepreneurs, i.e. part of investment which does not depend on endogenous factors, but it reflects exogenous emotions of entrepreneurs. We will assume that A is stationary.[1] It is necessary to include real output as one determinant

[1] $\lim_{t\to+\infty} |A_t| < +\infty$

of gross investment I, since I is nonstationary (it grows roughly at the same rate as real output) and r is stationary (roughly constant over time). Regression of stationary ($I(0)$) variable on nonstationary ($I(1)$) variable would lead to inconsistent estimate. The parameter χ (constant) is strictly greater than zero, what captures the positive relationship between I and Y.

One can model the financial (money) market following Jarlusic (1989) as supply of credit and demand for credit. Actors in this drama are firms, commercial banks and central bank. Firms demand for credit to finance production and for transactional, precautionary and speculative purposes. Central bank provides liquidity for commercial banks and commercial banks supply credit. The supply of credit at time t can be expressed as follows

$$C_t^S = E_t r_t^\alpha Y_t^\beta, \tag{2.6}$$

where C_t^S is real amount of credit actually supplied at time t, the term $E > 0$ stands for shock to monetary policy or financial innovations of commercial banks, constants α, β are greater or equal than zero.

Such a specification involves all three types of money supply depicted in figure 2.1. If $\alpha = 0$, then amount of credit supplied does not depend upon interest rate at all, so the money supply curve is vertical. This is the case of the Monetarist supply curve M_v^S. On the other hand, if α approaches to infinity then the money supply curve is infinitely elastic. This is the case of horizontalist approach towards monetary endogeneity represented by the money supply curve M_h^S. Last but not least, the case of $\alpha \in (0, 1)$ corresponds to the money supply curve M_i^S. Amount of credit supplied increases as r increases (first derivative of C^S is positive), however it increases by decreasing rate (since second derivative is negative). The concavity of C^S is because of risk aversion of banks.

What remains is to explain the role of the coefficient β. According to Jarlusic (1989) higher Y can be an indicator of higher profits for banks, therefore they can be willing to provide more credit. That is why, the coefficient β again determines the risk attitude of banks.

The demand for credit has the following form

$$C_t^D = B_t r_t^\kappa Y_t^\gamma, \tag{2.7}$$

where constants $\kappa \in (-1, 0)$ and $\gamma > 0$. The term B represents shocks to liquidity preference and can be interpreted as precautionary demand for money

(i.e. if there is emergency, firms and consumers demand more money ceteris paribus). This specification also involves transactional demand and financial demand (the term Y^{γ}) and speculative demand (the term r^{κ}).

We will assume that financial market clears in each period, i.e.

$$C_t^D = C_t^S.$$

It is convenient to briefly describe all three monetary policy views now. Let us begin with the Monetarist view. Monetarists contend that trend growth of money stock is determined by shifts of vertical money supply curve and that money is demanded especially for transactional purposes, i.e. money demand curve shifts to the right when Y increases. This implies that money stock grows over time and interest rate is relatively stable in time what corresponds to stylized facts. The equations (2.6) and (2.7) become

$$C_t^S = E_t,$$

$$C_t^D = B_t r_t^{\kappa} Y_t^{\gamma},$$

where the coefficient κ is relatively small (close to zero) because speculative motive is not dominant, the term B is relatively stable in time (stationary) because money demand curve is relatively stable according to Monetarists and the term E is not stationary because Monetarists believe that money supply does not depend upon Y and is determined only by wishes of central bank. Let us illustrate dynamic behavior of the "Monetarist"system by the figure 2.2.

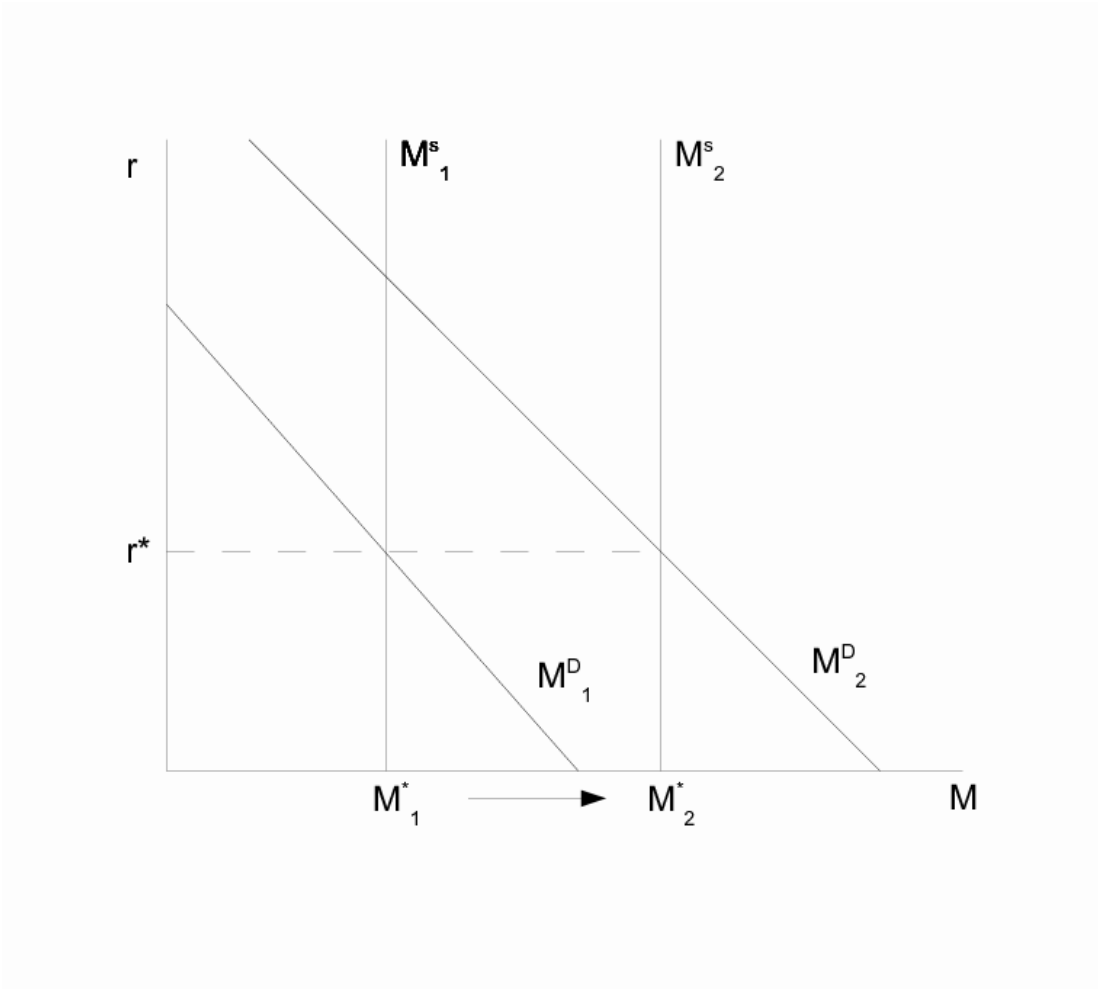
The economists who advocate horizontalist approach towards monetary endogeneity contend that the stock of money grows over time because of shifts of demand for money. These shifts are caused by GDP growth, i.e. money is used for transactional and financial purposes. The financial system only sets costs of borrowing (interest rate). That is why, the equation (2.6) becomes

$$r_t = E_t$$

and the equation (2.7) remains unchanged. Both shocks E and B are stationary now. So the system evolves over time according to the figure 2.3.

Last but not least, we will briefly describe evolution of the system with upward sloping money supply curve over time. In such a case, both curves shift over time. This simultaneous shift causes the stock of money to grow

Figure 2.2: Dynamic evolution of the "Monetarist"system



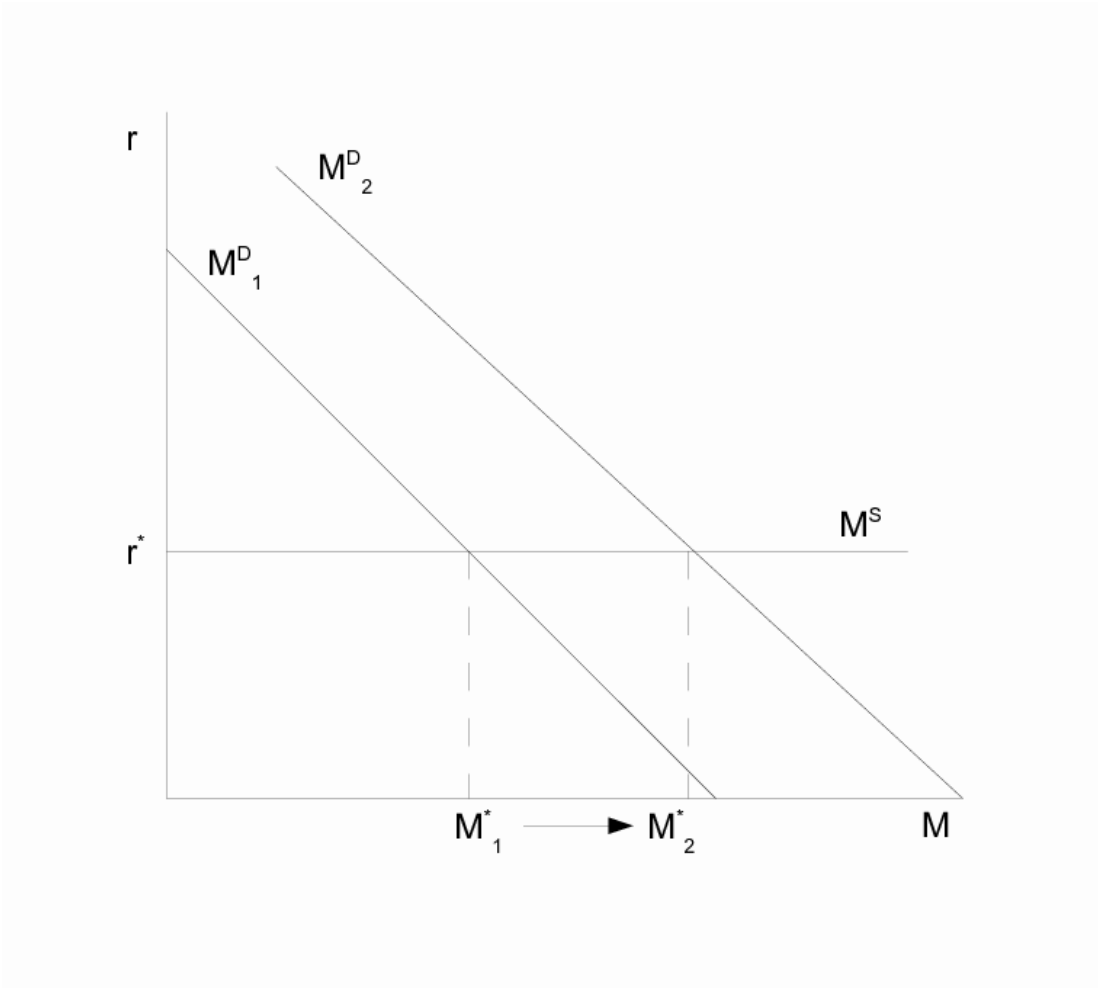
and interest rate to be stable. Equations (2.6) and (2.7) remain the same and shocks E and B are stationary. Let us illustrate this by the figure 2.4.

If α and β are "sufficiently"small (i.e. close to zero), than the system evolves most likely according to the Monetarist theory, money is exogenous. On the other hand, if α or β is "sufficiently"large (i.e. significantly different from zero), than the system evolves most likely according to the theory of endogenous money.

This was the trend behavior of the supply-demand system described by the equations (2.7) and (2.6). The business cycles dynamics of this system will be investigated in the next section by means of econometric techniques.

To describe the behavior of the general price level P let us express P as a mark-up over average labor costs according to Weintraub (1974)

Figure 2.3: Dynamic evolution of the system with horisontal supply of money

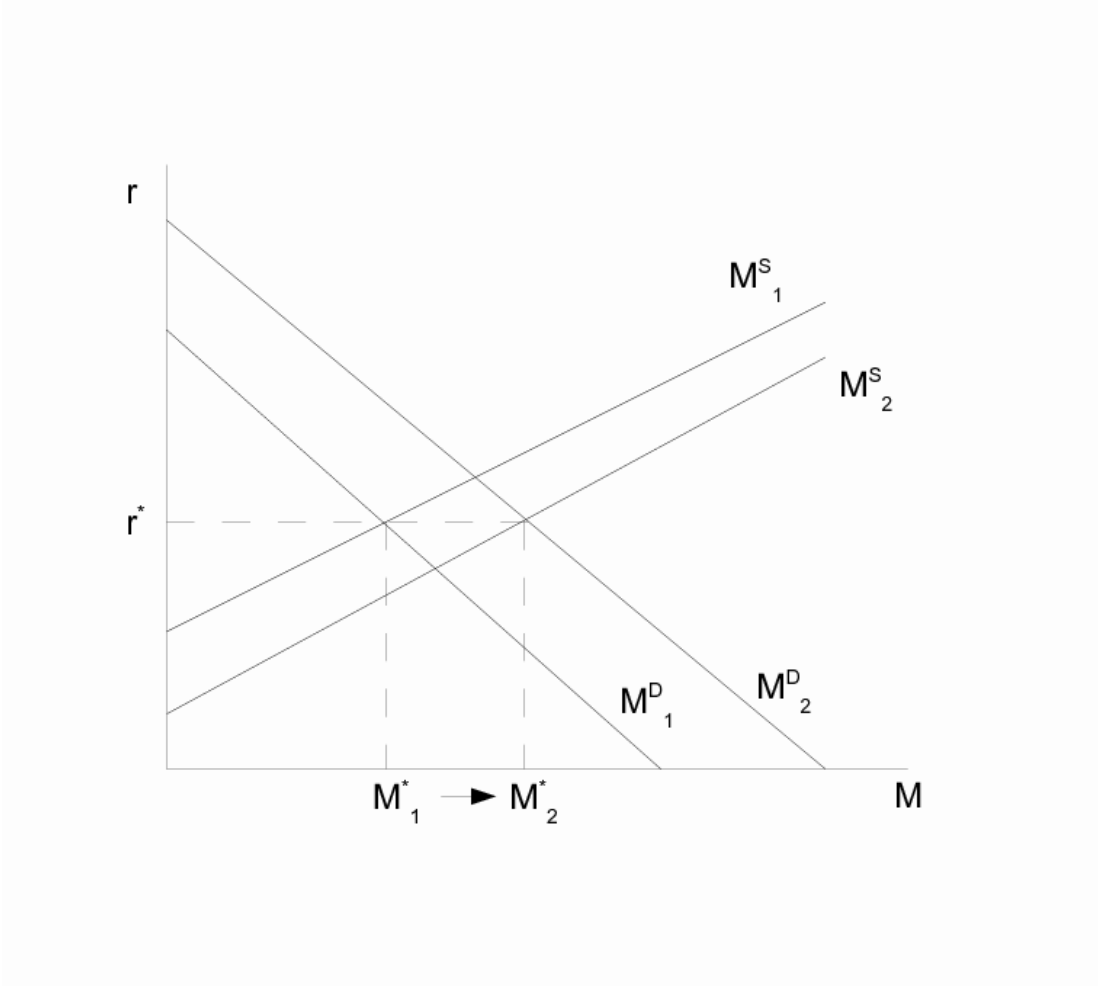


$$P_t = (1 + \mu_t)\frac{w_t L_t}{Y_t}, \tag{2.8}$$

where w_t is average nominal wage rate per worker, the ratio $\frac{Y_t}{L_t}$ is productivity of labor and consequently $\frac{w_t L_t}{Y_t}$ are labor costs per unit of output. The mark-up $1+\mu_t$ includes costs of capital as well so it depends upon interest rate, price of investment goods etc.

As pointed out in Jarlusic (1989), the model described in this section (which is based on endogenous money connected with effective demand) creates endogenously generated and self sustaining business cycles. In other words, market economy is inherently unstable. These are volatile investment decisions what cause business cycles fluctuations according to this model. Therefore,

Figure 2.4: Dynamic evolution of the system with upward sloping supply of money



the two hypotheses which arise from this model are: money is endogenous and GDP significantly responds to investment shocks. These hypotheses will be empirically tested in the next chapter.

Since the Post Keynesian economics pays attention to reality of assumptions not much to empirical verification of hypotheses, author does not know about any other study which tries to empirically verify hypotheses in Jarlusic (1989). So this thesis is a fairly pathfinder work.

One more note concerning economic policy: Since market economy is inherently unstable according to this model, stabilizing inherent instability is more appropriate tool than direct control of monetary aggregates or interest rates. For the purpose of stabilization, fiscal policy and regulatory policy can be used.

2.3 Justification of nominal rigidity

This section is an analogy to the section 2.1. It describes development of the Neo Keynesian and the New Keynesian economics mainly with emphasis on nominal rigidities. Why do nominal rigidities exist? What role do they have in generating business cycles fluctuations? Are they the main source of business cycles? Both streams of economics thought try to answer these questions and this section outlines their answers.

2.3.1 The role of nominal rigidities in the Neo Keynesian economics

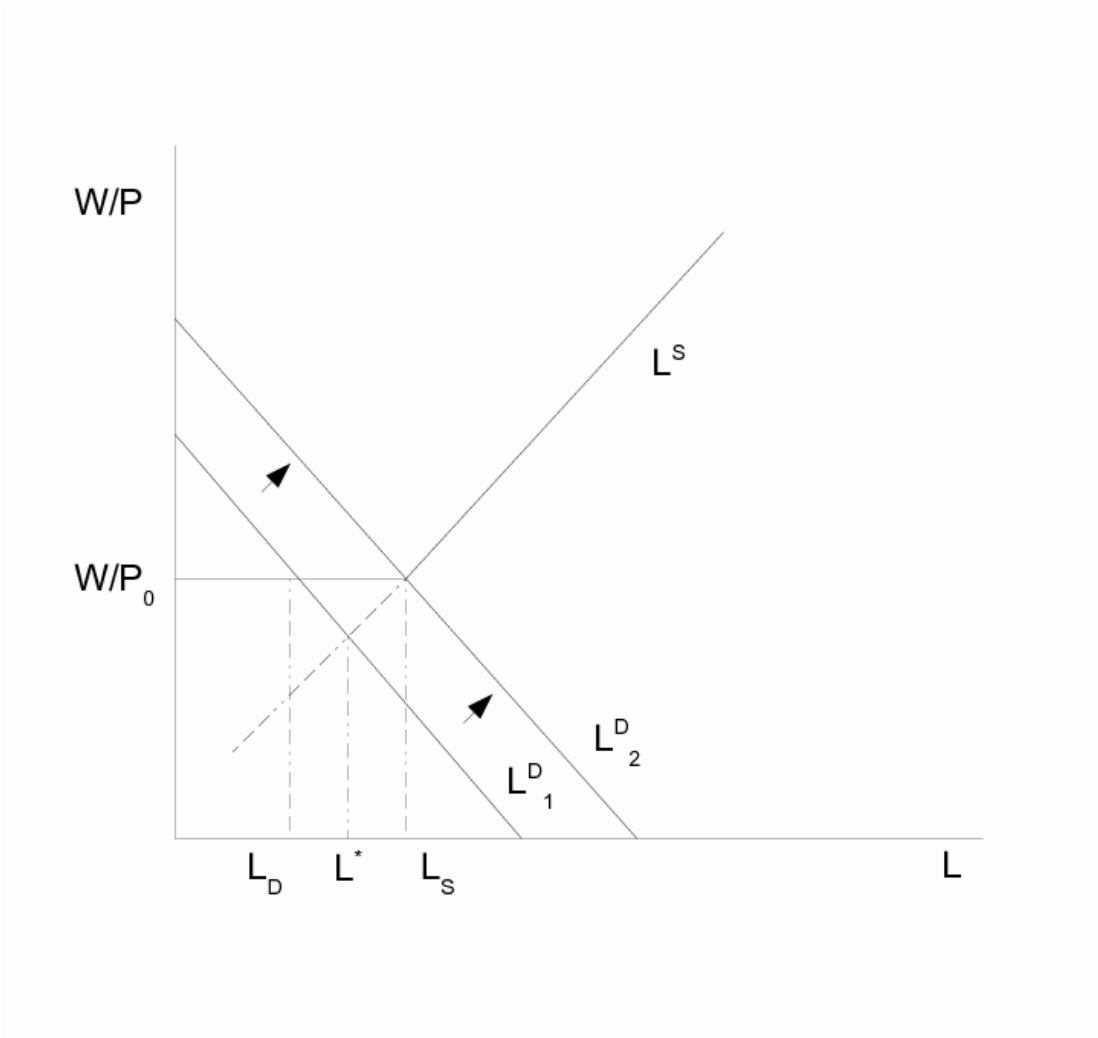
The Neo Keynesian economics came into existence as one of interpretations of the Keynes‘ General Theory connected with names J. R. Hicks, P. A. Samuelson, R. Harrod, E. Domar, J. Meade, F. Modigliani and later J. Tobin. Its main aim was to explain causes of involuntary unemployment and to propose policy tools to eliminate it. There exist three reasons why labor market does not clear according to this stream of economic thought - liquidity trap, investment trap and nominal rigidity. Contrary to this, Post Keynesians assert that the main cause of involuntary unemployment is fundamental uncertainty.

Since liquidity and investment trap is not likely to happen, nominal rigidity (mainly wage rigidity) was considered to be the main cause of involuntary unemployment. Despite this fact, only little attention was paid to explanation why wages are rigid. Wage rigidity was regarded as empirical fact. This was subject to critique of the New Classical macroeconomics, which together with the Monetarism became mainstream after oil shocks in the seventies.

Therefore, Neo Keynesian economists recommended using expansionary fiscal policy. The goal of the fiscal policy was to shift labor demand curve into the point with no involuntary unemployment. This demonstrates the figure 2.5. The difference between L_S and L_D is involuntary unemployment. When the real wage is $(\frac{W}{P})_0$, workers want to supply L_S hours of labor, but firms demand only L_D hours. This disequilibrium can not be removed because of labor market frictions. The equilibrium amount of labor without frictions is L^*. At this point there is no involuntary unemployment. All workers who want to work can find job. Involuntary unemployment can be eliminated by expansionary fiscal policy according to Neo Keynesians. Expansionary fiscal policy

shifts the labor demand curve upwards. This shift can result in elimination of involuntary unemployment. The new equilibrium amount of labor is L_S.

Figure 2.5: Nominal rigidity as a cause of involuntary unemployment



2.3.2 The role of nominal rigidities in the New Keynesian economics

Nominal rigidity was not considered as cause of business cycles fluctuations in RBC models. It was assumed that prices and wages are flexible and that competition is perfect. Productivity shocks generate business cycles fluctuations in RBC models instead of nominal rigidity and changes in autonomous investment as within the Neo Keynesian framework. The New Keynesian economics tried to overcome crisis of the Keynesism after oil shocks and did not

repeat "mistake" of the Neo Keynesian economics. They tried to explain why it is convenient for an individual firm to fix price of its output or inputs. So nominal rigidity is no longer empirical fact, it is optimal from the perspective of an individual firm, but it creates negative externality on macroeconomic level; labor market need not clear, involuntary unemployment can exist and market adjusting process need not lead to "happy" equilibrium as in RBC style models.

Why to introduce nominal (or real) rigidities? The reason is that observed positive correlation between inflation and cyclical output is hard to simulate by standard RBC models what is explained e.g. in Yun (1996). If positive productivity shock arrives, then it should increase output but decrease price level according to RBC theory, but it is not consistent with empirical observations. That is why, contemporary trend is to incorporate various nominal and real rigidities into modern dynamic stochastic general equilibrium model (DSGE), where rigidities amplify impact of external shocks (mainly monetary shocks). Blanchard (2000) also concludes that this is a contemporary trend, to incorporate rigidities (imperfections) into DSGE models. So macroeconomics has the common framework now as it had in the 50‘s, 60‘s and in the early 70‘s (IS-LM model etc.).

What are the motivations for firms to fix prices? One possible explanation is the so called menu costs, i.e. costs of price changes. However, microeconomic evidence indicates that costs of reoptimatization are higher for firms than menu costs, see e.g. Christiano *et al.* (2005). This fact reflects the Calvo price (wage)-setting. Firms can reoptimize prices only with some probability otherwise they set prices according to realized inflation (see the next section).

2.4 The New Keynesian model

The typical New Keynesian model which incorporates various nominal and real rigidities is described in Christiano *et al.* (2005). Nominal rigidities are

- Calvo pricing (prices/wages can be adjusted with some probability)
- Monopolistic price setting
- Monopolistic wage setting
- Wage bill borrowing

Real rigidities are

- Habit formation in preferences
- Adjustment costs in investment
- Variable capital utilization
- Fixed costs of production

Such frictions are crucial for the New Keynesian model. Otherwise, positive monetary policy shock (decline in interest rate) would lead to immediate rise in costs of firms. This would mean neutrality of monetary policy as in RBC models what is not consistent with empirical observations.

Let us briefly describe this model and its main distinctions from the Post Keynesian model. The final good Y_t is produced by a perfectly competitive industry which uses CRTS technology (Stiglitz-Dixit production function) and continuum of intermediate goods.

The intermediate good Y_{jt}, $j \in (0, 1)$ is produced by a monopolist industry which uses capital and labor as inputs. To keep monopoly in the intermediate good sector valid, fixed costs of production ϕ are introduced and entry into sector is ruled out. This implies positive economic profits. The firm must ensure financial resources to pay workers (wage bill $W_t L_{jt}$) in advance, i.e. to borrow them from the financial intermediary.

The firm can reoptimize price of its output only with the probability $1 - \xi_p$ (Calvo pricing), i.e. with the probability $1 - \xi_p$ the firm sets P_{jt} so as to maximize the expected value of future profits. With the probability ξ_p firm adjusts the price of its output according to a simple rule. Christiano *et al.* (2005) consider two price adjusting schemes. The first one is

$$P_{jt} = \overline{\pi} P_{j,t-1},$$

where $\overline{\pi}$ is trend inflation. The second one is

$$P_{jt} = \pi_{t-1} P_{j,t-1}.$$

The second price adjusting scheme creates stronger inertia of inflation.

The first order conditions which result from the firm's price setting choice yield that the firm sets price of its output as a mark-up over expected marginal costs. This is relatively similar to the Post Keynesian price setting mechanism described by the equation (2.8). The difference is that firms set the price of its output as a mark-up over average labor costs instead of over total marginal costs. Therefore, mark-up depends upon interest rate and price of investment goods in the Post Keynesian model.

Households' behavior is standard: they maximize expected discounted utility. However, household's utility function u exhibits habit formation in consumption preferences, i.e. utility function has the following form

$$u(c_t, c_{t-1}) = f(c_t - bc_{t-1}),$$

where u is a bivariant function and f is a function of one variable. This means that the utility from consumption depends upon change in consumption rather than upon absolute value of consumption. This is because standard time-separable preferences are not able to generate hump-shaped rise in consumption after positive monetary shock (Christiano *et al.* 2005, p. 13). Household's utility depends upon labor supplied and upon amount of real cash balances held by the household as well. These relations are described by the functions z and v respectively. Households maximize expected discounted utility subject to the resource constraint which describes evolution of household's asset over time. This behavior of households is very different from the behavior of households in the Post Keynesian model, where households simply save a constant fraction s_w of their wage income and consume the remaining part.

Household is also monopoly supplier of a differentiated labor service h_{jt}. Then the competitive firm transforms labor services of households into an aggregate supply of labor by the Stiglitz-Dixit production function (see final good sector). The situation is the same as in the case of the intermediate good producer. The household can reoptimize its wage only with the probability $1 - \xi_w$.

With the probability ξ_w, household sets the wage according to one of the two following rules

$$W_{jt} = \overline{\pi} W_{j,t-1}$$

and

$$W_{jt} = \pi_{t-1} W_{j,t-1}.$$

This has similar consequences as for the intermediate good producer. The household sets the real wage as a constant mark-up over expected marginal rate of substitution between consumption and leisure (Christiano *et al.* 2005, p. 17). This wage setting is very different from the Post Keynesian model. The real wage operates in the Post Keynesian model in order to create enough savings to cover planed investment. So it is not set by households, but it is determined by investment decisions of entrepreneurs.

Adjustment costs of investment represented by the bivariant function F transform current and past investment into installed capital. The reason for introducing this real rigidity is that it enables a hump-shaped response of investment to the monetary policy shock (Christiano *et al.* 2005, p. 18).

The crucial assumption of this model is variable capital utilization (real rigidity). It prevents from sharp rising of marginal costs after the monetary policy shock.

It remains to explain the role of the financial sector in this model. The financial sector receives resources from households and from monetary authority and provides them to firms and firms consequently pay wage bill to households. From the Post Keynesian point of view, such a model of financial sector is unrealistic, because it does not consider credit creation mechanism. In other words, this New Keynesian model assumes only exogenous supply of money. There are some New Keynesian papers which tackle a problem of endogenous money (e.g. Ireland (2003) and Yun (1996)). However, these articles assume only reaction of monetary authority to endogenous variables (e.g. Taylor rule) not endogeneity of money in more fundamental sense (credit creation) considered by the Post Keynesian economics. This aspect distinguishes the New Keynesian and the Post Keynesian model at most.

The aim of the Christiano *et al.* (2005) model is to explain observed inertia of inflation and persistence of output, investment and consumption after the monetary shock. They conclude that monopolistic wage setting and vari-

able capital utilization contribute to these observed empirical characteristics at most.

Chapter 3

Econometric models

The aim of this chapter is to empirically verify hypotheses from the theoretical part of this thesis (i.e. whether money is endogenous, whether GDP fluctuations are caused by investment shocks or by interest rate shocks etc.) The method of vector auto-regression will be utilized. Impulse-response functions and forecast error variance decomposition (FEVD) will be used to investigate business cycles dynamics.

3.1 Reduced-form VAR model

This section seeks to identify key business cycles facts. The identification will be done by the following reduced-form VAR model

$$Z_t = a_0 + \sum_{s=1}^{p} a_s Z_{t-s} + u_t,$$

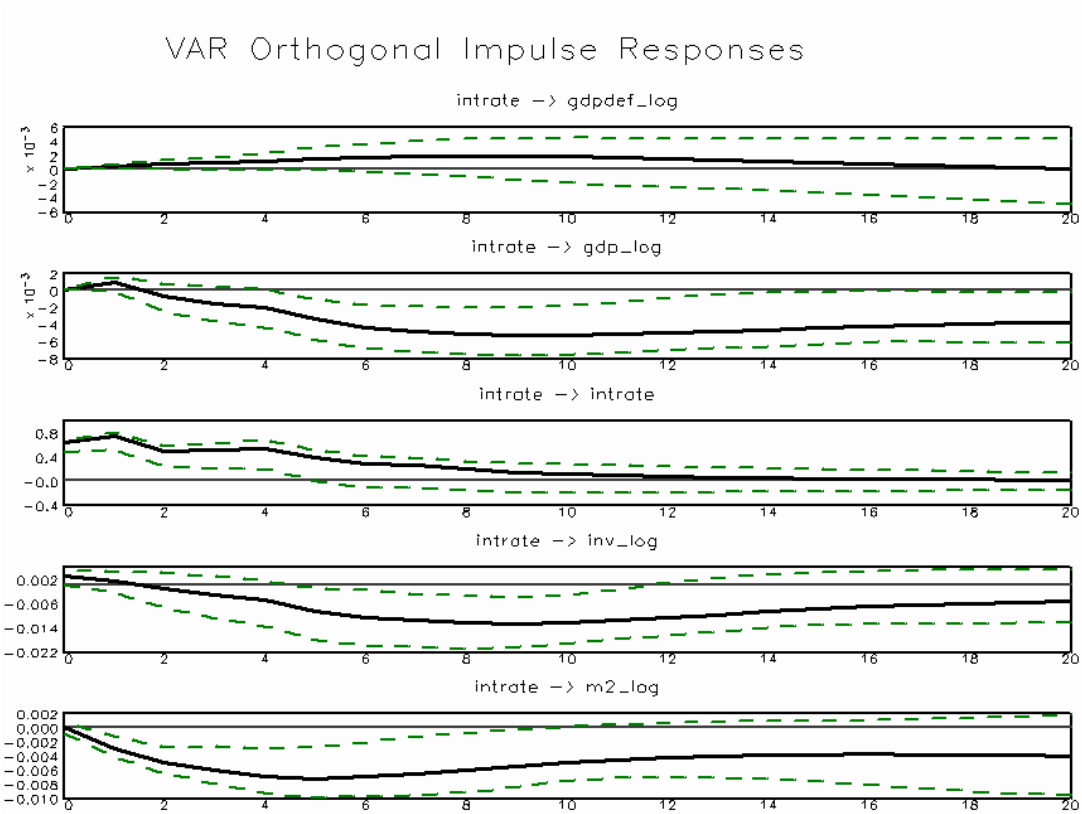
where Z_t is vector of data collected at time t, u_t is prediction error at time t, a_0, is a vector of estimated coefficients and a_s $s = 1, ..., p$ are matrices of estimated coefficients.

The vector Z_t contains real gross domestic product, GDP implicit price deflator, 3-month treasury bill rate, M2 money stock and real private fixed investment. All variables with the exception of Treasury bill rate are in logarithms. Data are collected from the US economy over the period 1959 q1 - 2009 q4. Four lags of vector Z_t were included, i.e. $p = 4$. This number of lags is optimal according to Akaike Info Criterion and Final Prediction Error.

3.1.1 Impulse-response analysis

Results of estimation are available in Appendix A. They indicate that the system we analyze is stable, since all eigenvalues of the reverse characteristic polynomial lie outside unit circle in absolute values. This means that we can depict business cycles dynamics by means of impulse-response functions. They plot response of all variables to orthogonalized innovation in prediction error in one variable. The figure 3.1 depicts response of all variables to impulse in the bill rate.

Figure 3.1: Response to interest rate shock in a reduced-form VAR model



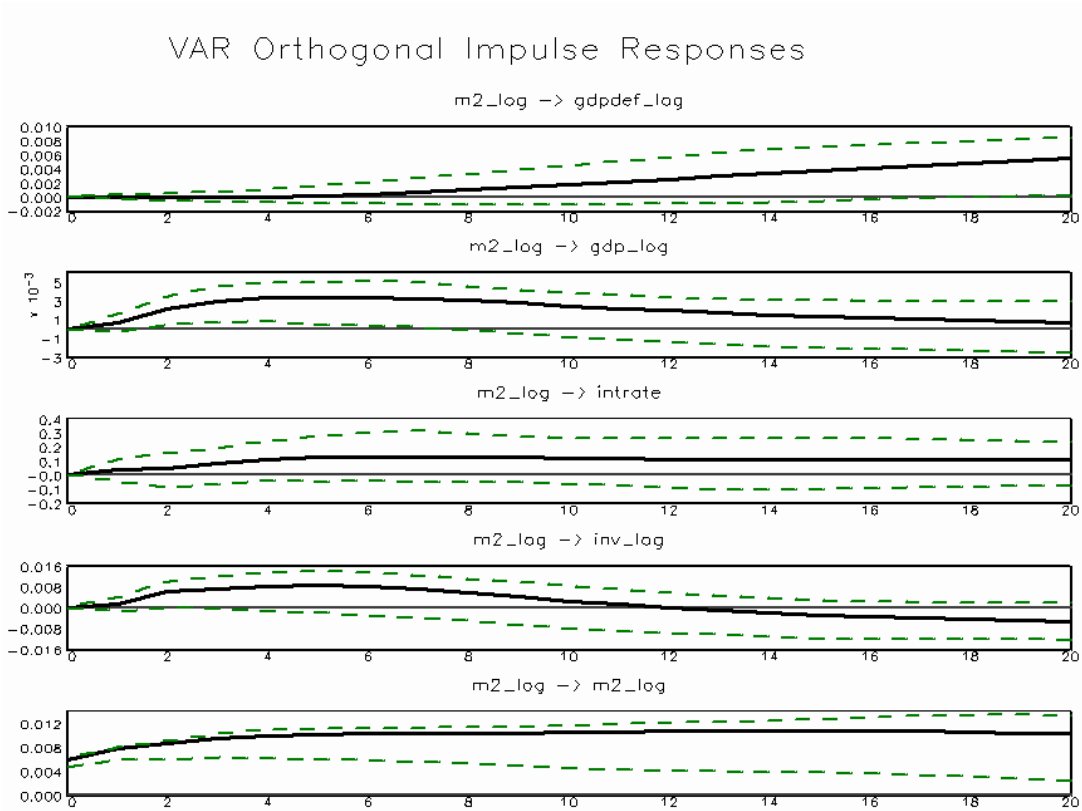
Results are interesting. The first graph shows that price level measured by GDP deflator does not significantly respond to increase in interest rate and the second graph shows that output responds negatively to the same shock. This is remarkable result. It indicates that monetary policy based on interest rates manipulations is ineffective. Endeavor to reduce inflation by raising interest rates will result in decline of output and rise of unemployment but not in reduction of inflation. The decline of output takes 14 quarters, from 4th to

18th quarter, what is a relatively long period. This finding supports the New Keynesian hypothesis that GDP fluctuations are driven by exogenous interest rate shocks.

Other results are not surprising. Investment activity declines after interest rate shock (see the investment function). The decline takes 5 quarters. The money stock also responds negatively. The negative relationship between money stock and interest rate captures demand for money. The interest rate gradually declines to its long-run level after shock.

The figure 3.2 depicts the response of the system to the money supply shock. This money supply shock can be interpreted as an act of a monetary authority to enhance growth of money stock (the Monetarist view) or as an endogenous act of commercial banks (financial innovation, credit creation etc. - the Post Keynesian view).

Figure 3.2: Response to money supply shock in a reduced-form VAR model

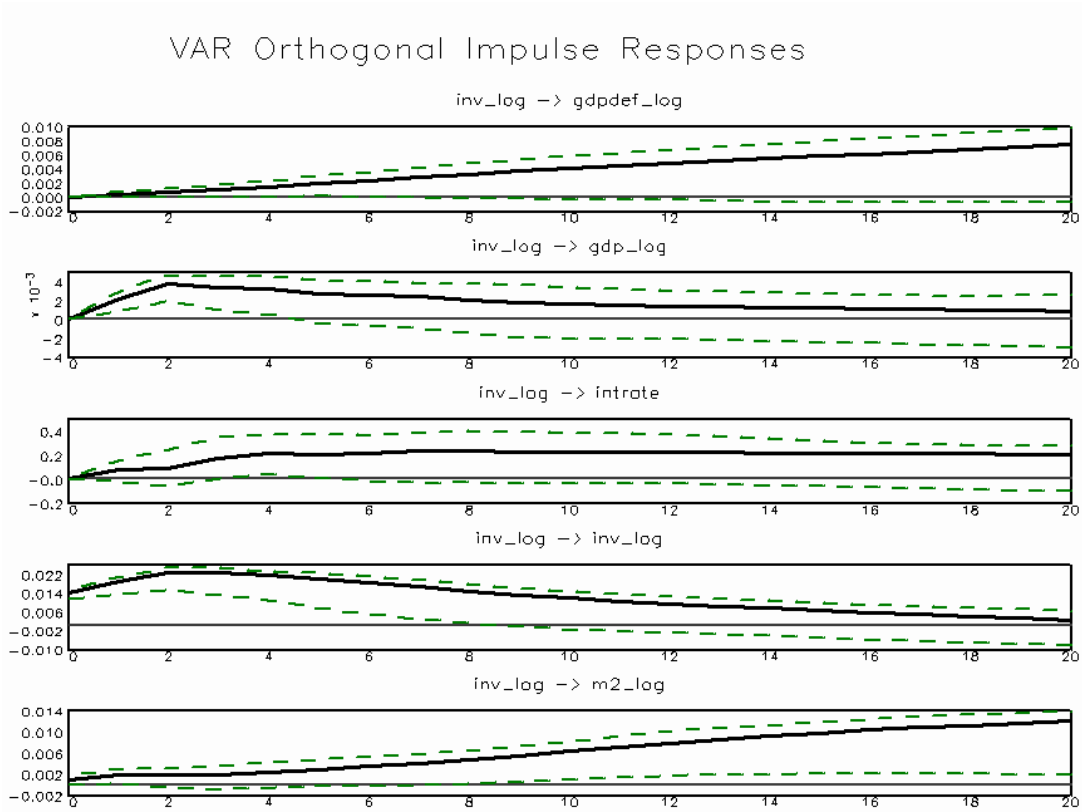


The first graph shows that price level does not respond to increase in money stock. The second and the fourth graph show that positive money supply shock

can boost economic activity as measured by GDP. However, the effect takes relatively shortly, 4 quarters. Both figures 3.1 and 3.2 indicate very strong inertia of inflation, even stronger than what Christiano *et al.* (2005) found.

It is surprising that interest rate is not influenced by raise of money stock.

Figure 3.3: Response to investment shock in a reduced-form VAR model



The positive investment shock causes rise of GDP which takes roughly one year (see the figure 3.3, the second graph). The response of GDP is apparent and it indicates that investment decisions significantly influence the performance of economy. It also indicates that fiscal policy based on public investment (e.g. in infrastructure etc.) is effective and can promote growth of economy. This finding confirms the Post Keynesian hypothesis that GDP fluctuations are driven by investment shocks.

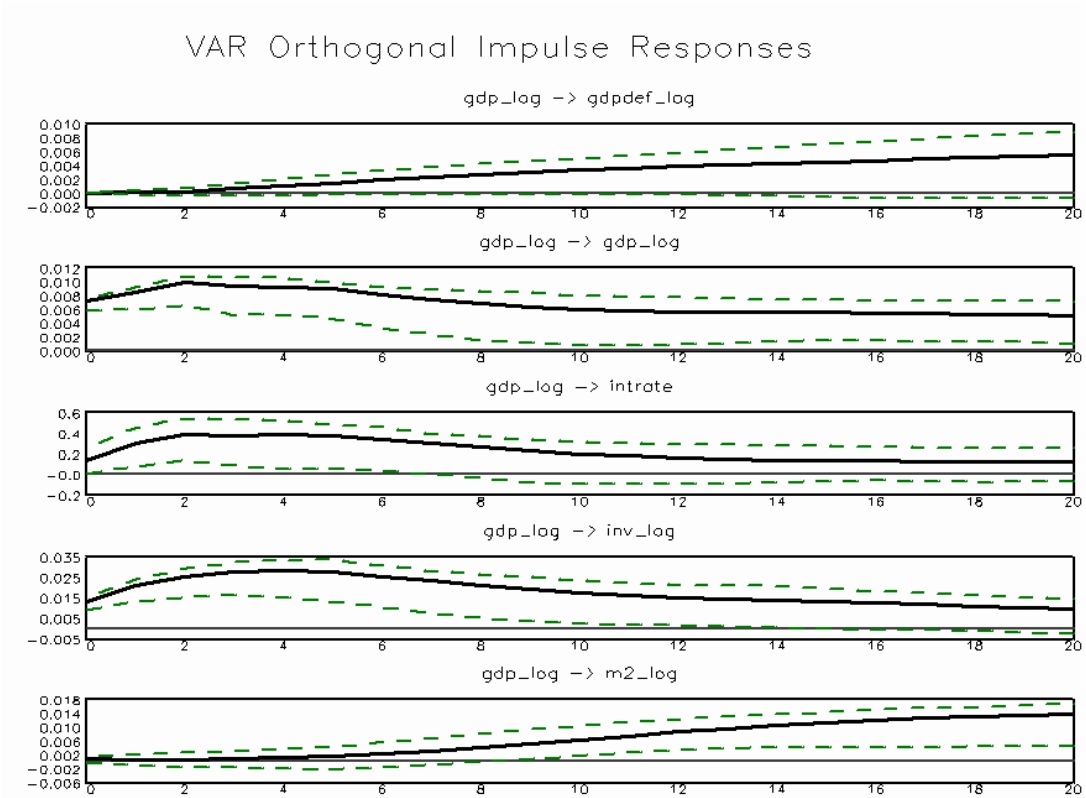
The first graph shows that the positive investment shock does not cause inflationary pressures. There is no rise of GDP deflator caused by the investment shock. It indicates that inflation is neither caused by expansion of stock of money nor by expansion of investment activity (for more profound analysis

see forecast error variance decomposition). It is likely that inflation is caused by factors which are not included in this empirical model (e.g. labor costs).

There is almost no response of interest rate (with the exception of slight rise in the fourth quarter). This is a bit strange. One would expect rise of interest rate after the positive investment shock.

Last but not least, money stock increases after the positive investment shock. Since output and investment increase, the more money is demanded due to transactional and financial purposes.

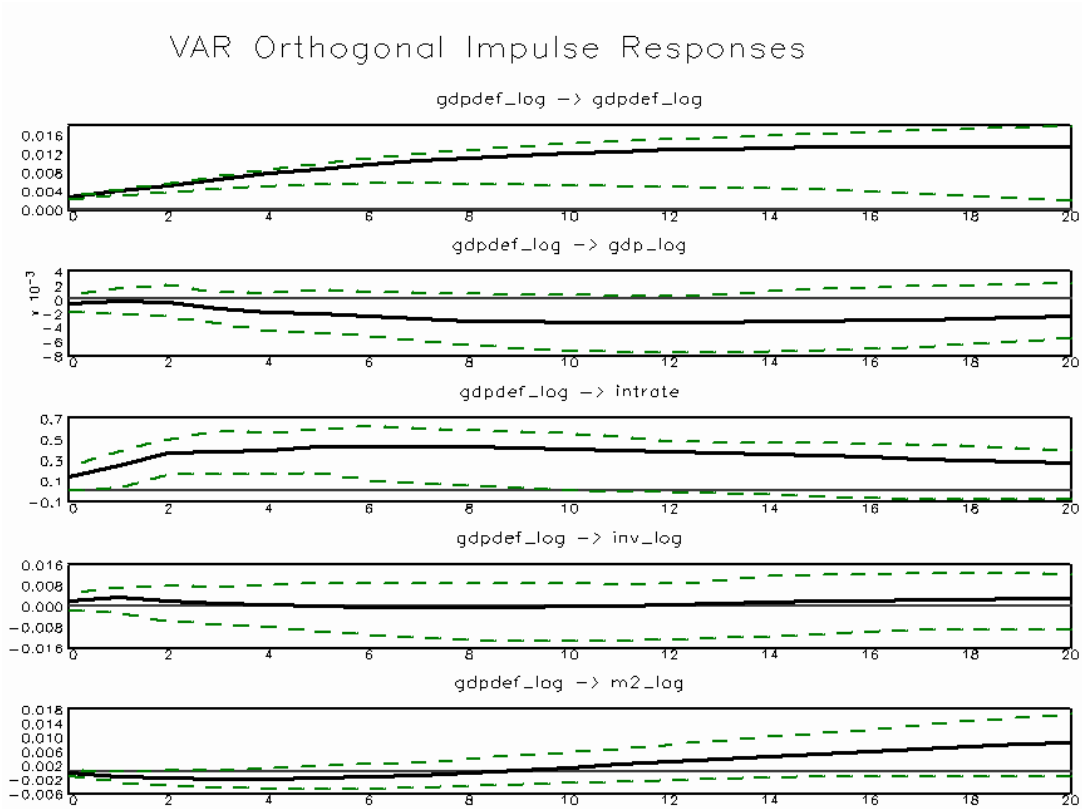
Figure 3.4: Response to GDP shock in a reduced-form VAR model



The figures 3.4 and 3.5 plot the response of the system to GDP and GDP deflator shock respectively. Such shocks do not have so straightforward interpretation as previous shocks. GDP deflator shock can be interpreted as rise of price of imported commodity (e.g. oil shock). It is surprising that there is no impact on GDP and investment (i.e. on real economy). Behavior of other variables is obvious.

GDP shock has significant effect on investment. It indicates that both variables are strongly linked together, since investment has significant effect

Figure 3.5: Response to GDP deflator shock in a reduced-form VAR model



on GDP and vice versa. It is strange that GDP shock does not cause rise of GDP deflator. Many studies proved that there is a strong positive correlation between cyclical measure of output and cyclical measure of price level (e.g. Yun (1996)). This correlation is not confirmed by this reduced-form VAR model.

3.1.2 FEVD analysis

The forecast error variance decomposition (FEVD) represents a different way how to analyze dynamic behavior of variables over the business cycle. The FEVD determines what fraction of forecast error in one variable is accounted for by forecast error in another variable. In other words, what fraction of variance of one variable is caused by another variable. It also separates the short-run and the long-run effects. It is a useful tool to analyze transmission channels of different shocks.

The most important variable for this thesis is GDP. Its FEVD depicts the figure 3.6. This analysis should answer whether the business cycle is caused by shocks of other variables or is a self generating process. In the short run, GDP fluctuations are caused by themselves. The weight of other variables increases in the long run. However, their weight is less than 40% even in the long run. It seems that results support our hypothesis that GDP fluctuations are self generating. However, it is possible that GDP fluctuations are caused by another variable not included into the model (e.g. productivity shocks) and that the weight of other variables is in fact greater.

Small weight of investment (less than 10%) is surprising. This seems to be in contradiction with the impulse-response analysis, which indicates a strong link between these variables. The same holds for the link between interest rate and GDP. The strong link suggested by the impulse-response analysis is not confirmed by the FEVD analysis, since interest rate variation causes only 20% of variation in GDP in the long run and even less in the short run. Other variables have even lower predictive power.

Let us investigate the behavior of price level as represented by GDP deflator now. Its FEVD depicts the figure 3.7. It is clear that GDP deflator is even more self generating than GDP. In the long run, more than 75% of fluctuations of GDP deflator is caused by themselves and almost 100% in the short run. Such a result is maybe due to omitting important variables which cause changes in domestic price level (exchange rate, labor costs etc.).

Several aspects are worth of mentioning. The influence of interest rate on GDP deflator fluctuations is negligible (2% and less). It is the same result as in case of impulse-response analysis. The stock of money has also small impact on GDP deflator fluctuations (at most 4%). It seems to contradict the Monetarist hypothesis that inflation is monetary phenomenon. Significant effect on GDP

Figure 3.6: FEVD of GDP in a reduced-form VAR model

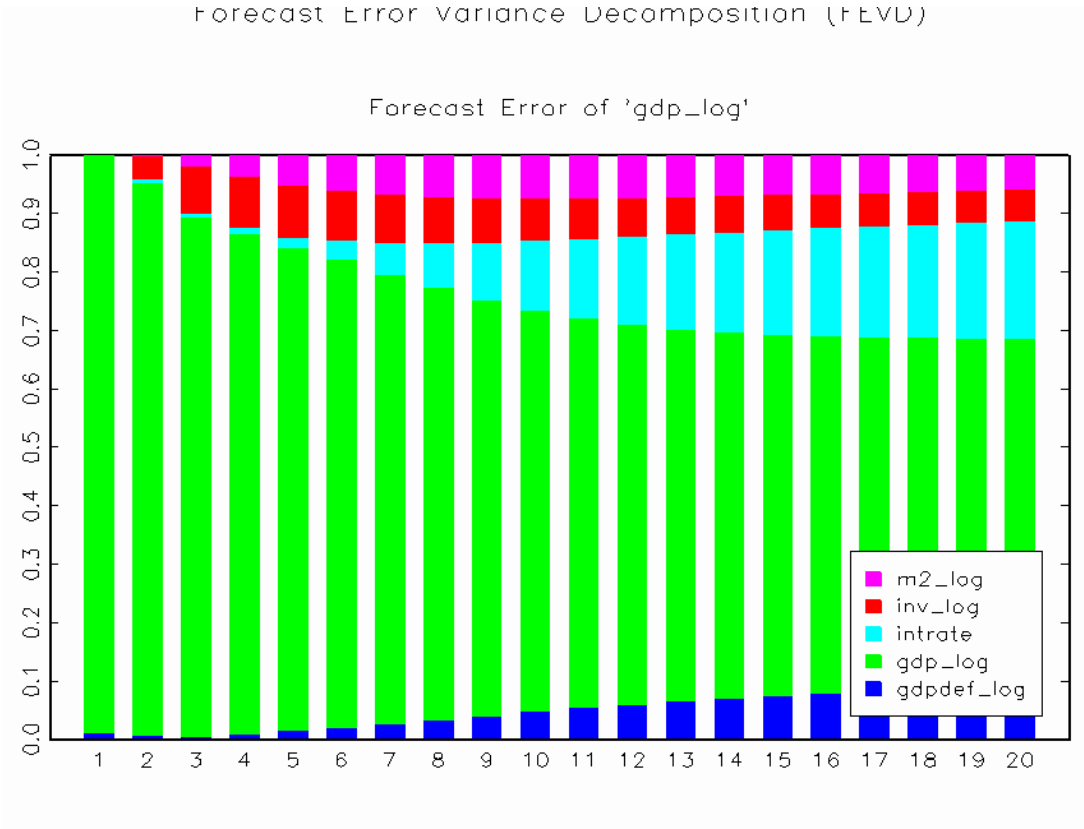
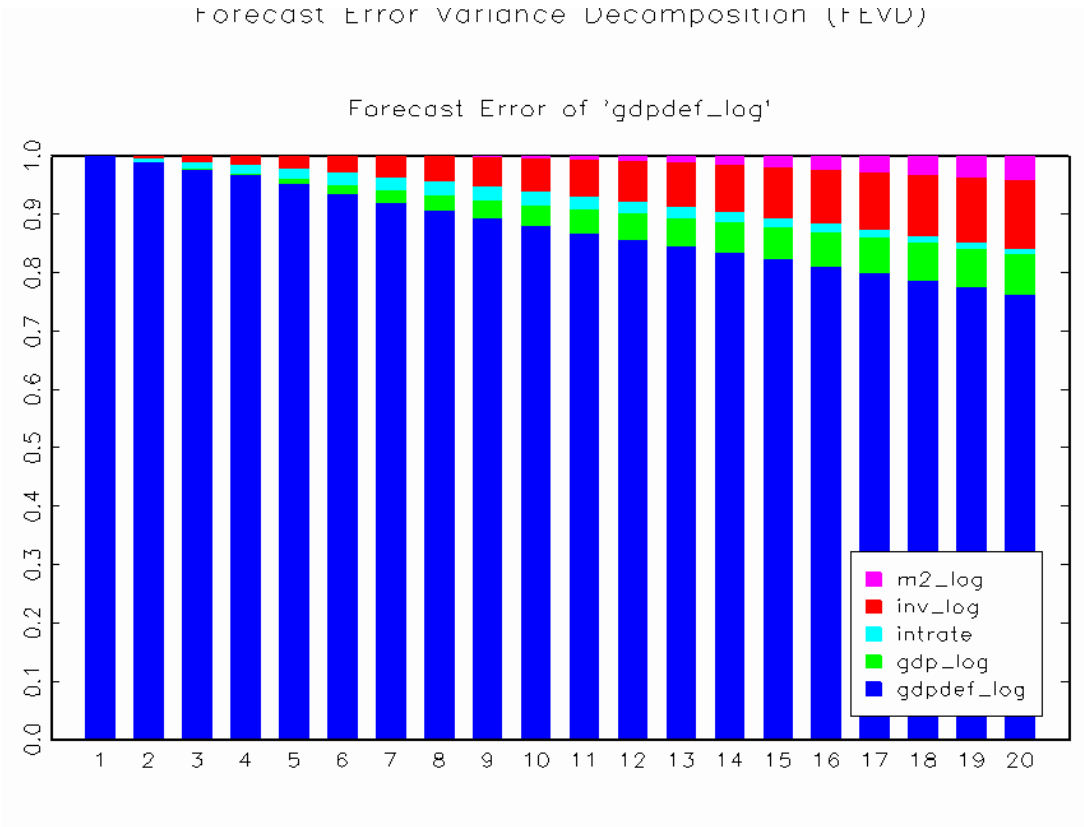


Figure 3.7: FEVD of GDP deflator in a reduced-form VAR model



deflator fluctuations has only investment (12% in the long run).

The FEVD analysis of M2 can be used to determine whether money is endogenous or not (see the figure 3.8). According to this figure, fluctuations of money stock are caused by themselves in the short run, i.e. money is exogenous in the short run. However, the influence of other variables increases in the long run. Investment and GDP cause 44% of fluctuations of M2. This indicates that a significant fraction of money stock exists due to variables which are not under the direct control of monetary authority. So money is more less endogenous in the long run (for more profound analysis see the section 3.2).

The influence of interest rate is strongest in the seventh and eighth quarter (26%) and then it is consequently getting weaker.

The figure 3.9 indicates that interest rate is one of the least exogenous variables. Only 31% of fluctuations of interest rate is not caused by other variables in the long run. The most important variable is GDP deflator in the long run (37%). This is interesting. One would expect that interest rate causes

Figure 3.8: FEVD of M2 in a reduced-form VAR model

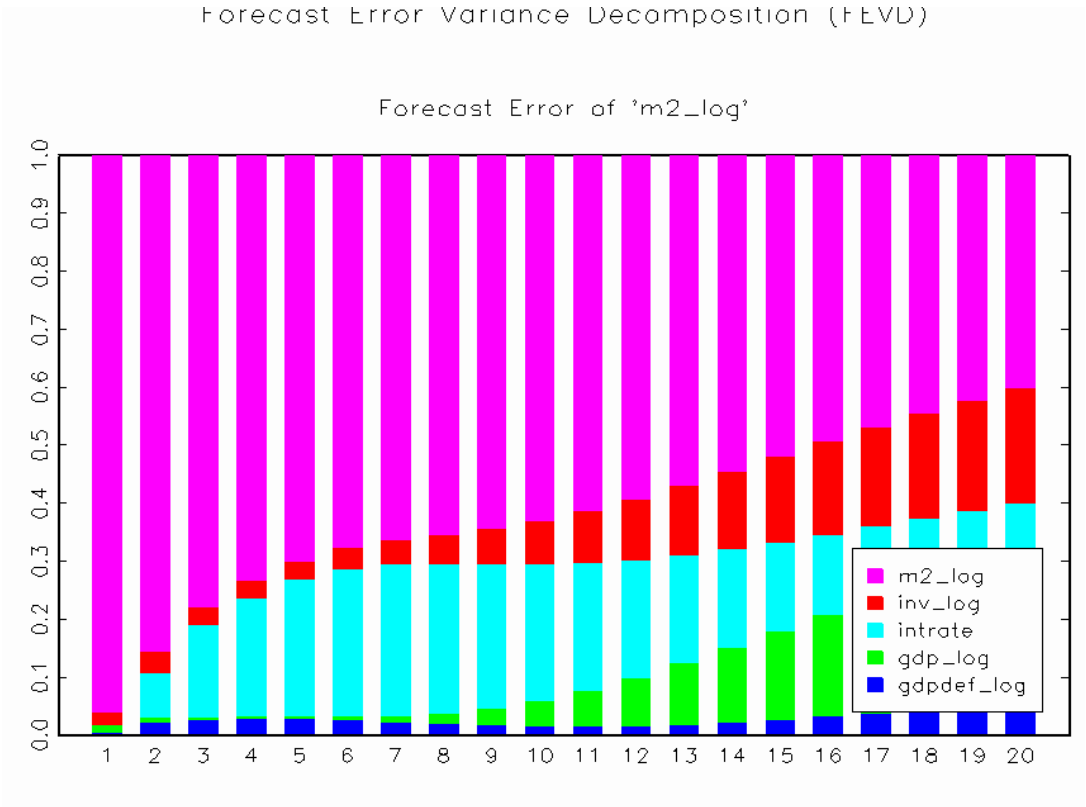
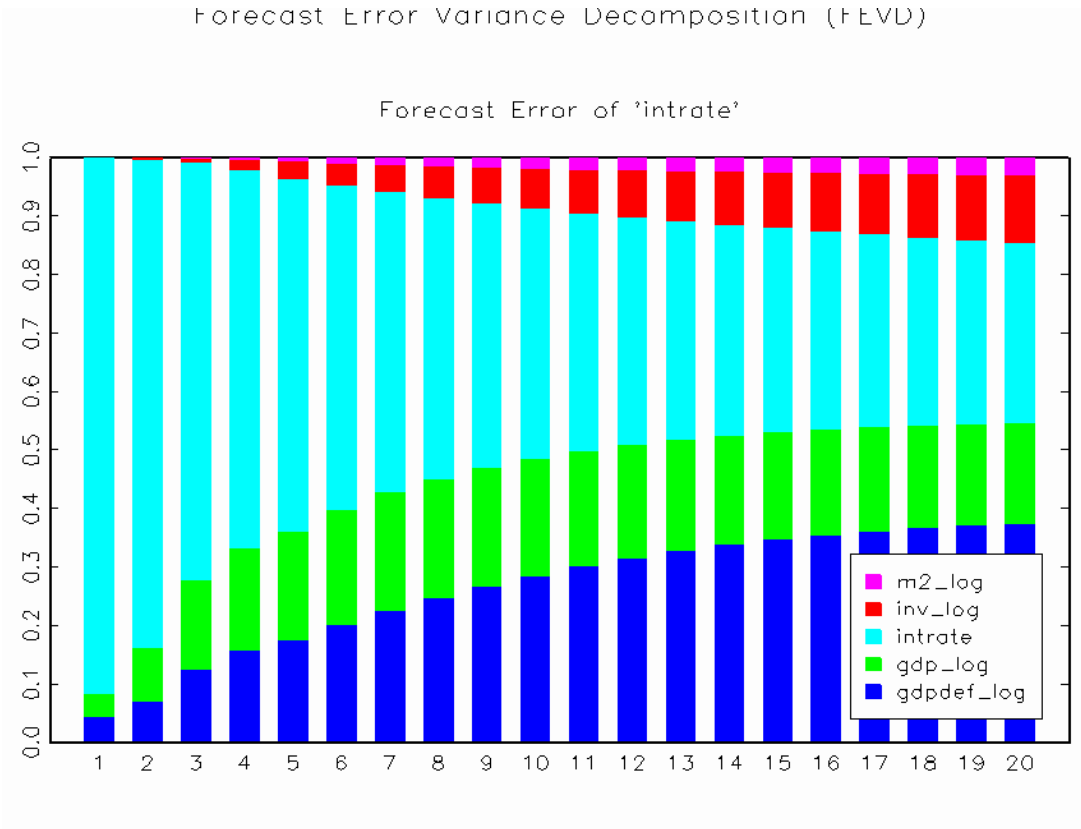


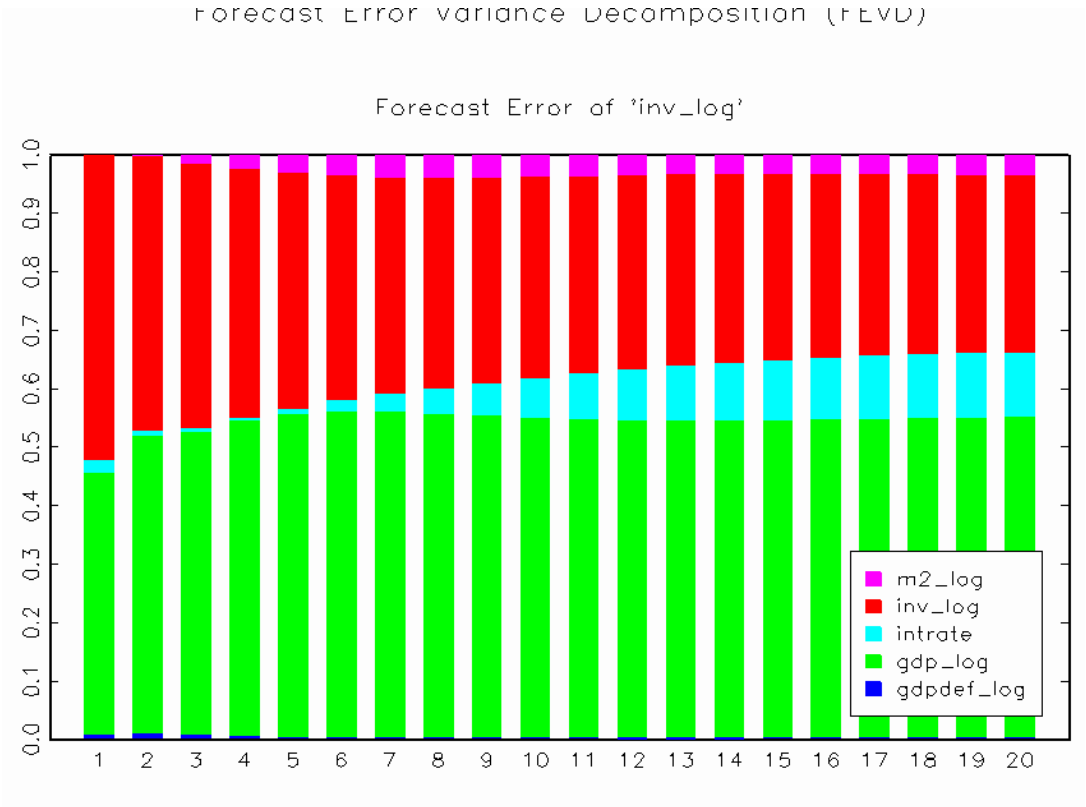
Figure 3.9: FEVD of interest rate in a reduced-form VAR model



fluctuations of price level not vice versa.

The figure 3.10 confirms that investment is strongly dependent on GDP (45% in the short run and 55% in the long run). It confirms the strong link of these two variables which was found by impulse-response analysis. Investment is even less exogenous than interest rate.

Figure 3.10: FEVD of investment in a reduced-form VAR model



3.2 SVAR model

Structural VAR is a more sophisticated econometric tool than reduced-form VAR, since it captures also contemporaneous effects. SVAR can be formally written as follows

$$BZ_t = a_0 + \sum_{s=1}^{p} a_s Z_{t-s} + u_t,$$

where the matrix of coefficients B captures contemporaneous effects. If the matrix B is regular, one can obtain the reduced-form VAR by multiplying SVAR equation by B^{-1} from the left. It yields

$$Z_t = A_0 + \sum_{s=1}^{p} A_s Z_{t-s} + e_t,$$

where $A_0 = B^{-1}a_0$, $A_s = B^{-1}a_s$ and $e_t = B^{-1}u_t$.

It is impossible to obtain all coefficients of SVAR from reduced-form VAR, since SVAR has more coefficients than reduced-form VAR. Therefore, it is necessary to restrict some coefficients of SVAR for identification. One way how to restrict coefficients of SVAR is the so called Choleski decomposition. However, this method will not be used in this thesis.

The theoretical model presented in the section 2.2 is appropriate for using another method described in Sims (1986). This method utilizes economic intuition, in comparison with Choleski decomposition what is more less technical method. Identification is achieved by separating money supply and money demand (i.e. to restrict some coefficients of the matrix B). Other sections demonstrate how various regimes of money supply can be estimated by the Sims (1986) method. The section 3.2.1 estimates model with horizontal supply of money (the Post Keynesian model) and the section 3.2.2 estimates model with vertical supply of money (the Monetarist model). Unfortunately, the third money supply regime (upward sloping money supply) is not identified by the Sims (1986) method and cannot be estimated.

3.2.1 Specification 1 (Model with horizontal supply of money)

The model with horizontal supply of money which is a slightly modified version of the theoretical model from the section 2.2 is as follows in matrix form

$$\begin{pmatrix} 1 & -\alpha_{12} & -\alpha_{13} & -\alpha_{14} & -\alpha_{15} \\ 0 & 1 & 0 & -\alpha_{24} & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & -\alpha_{42} & -\alpha_{43} & 1 & 0 \\ 0 & -\alpha_{52} & -\alpha_{53} & 0 & 1 \end{pmatrix} \begin{pmatrix} \log P_t \\ \log Y_t \\ r_t \\ \log I_t \\ \log M_t \end{pmatrix} = \begin{pmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \\ u_{4t} \\ u_{5t} \end{pmatrix}$$

or in structural equations

$$\log P_t = \alpha_{12} \log Y_t + \alpha_{13} r_t + \alpha_{14} \log I_t + \alpha_{15} \log M_t + u_{1t} \tag{3.1}$$

$$\log Y_t = \alpha_{24} \log I_t + u_{2t} \tag{3.2}$$

$$r_t = u_{3t} \tag{3.3}$$

$$\log I_t = \alpha_{42} \log Y_t + \alpha_{43} r_t + u_{4t} \tag{3.4}$$

$$\log M_t = \alpha_{52} \log Y_t + \alpha_{53} r_t + u_{5t} \tag{3.5}$$

The equations (3.3) and (3.5) represent supply of and demand for money respectively. The supply of money is horizontal, since monetary authority is only able to set costs of borrowing and is not able to directly control amount of money in economy according to the horizontal approach towards endogeneity of money. The equations (3.2) and (3.4) are analogy of the equations (2.1) and (2.5) from the theoretical model. The equation (3.1) is analogy of the equation (2.8), however other variables are used instead of average wage (hoping that are correlated with average wage) to keep the model manageably small.

Results of estimation are reported in the Appendix in the section A.2.1. However, we are more interested in dynamic behavior of the estimated system. We utilize impulse response functions and FEVD as in the case of reduced-form VAR.

If we have a look at graphs which depict SVAR impulse-responses (figures 3.11,... 3.15), we will see that they do not differ from reduced-form VAR impulse-responses so much. Let us investigate response to interest rate shock (see the figure 3.11). Price level does not respond at all to interest rate shock. This corresponds to what we found in the previous section in the case of reduced-form VAR. Response of GDP, investment and money stock is also similar (transitory decline).

The figure 3.12 depicts response to investment shock and the picture is again very similar to what we obtained in the previous section. Price level does

Figure 3.11: Response to interest rate shock in SVAR model, Specification 1

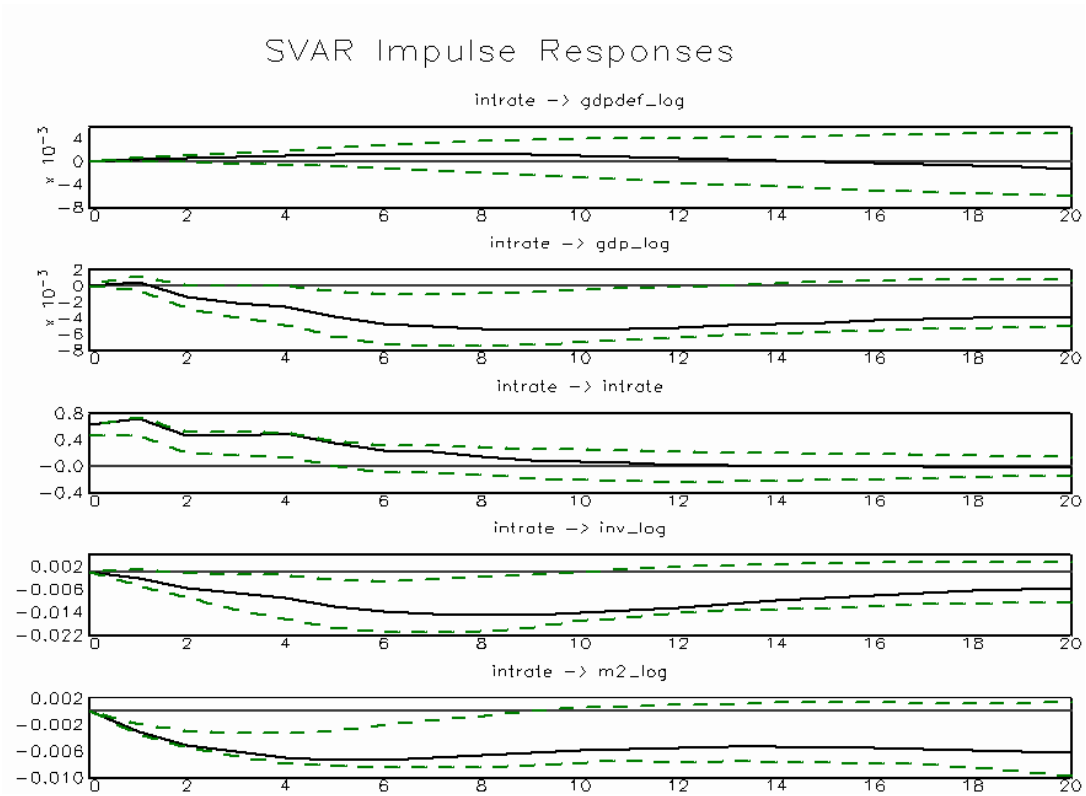


Figure 3.12: Response to investment shock in SVAR model, Specification 1

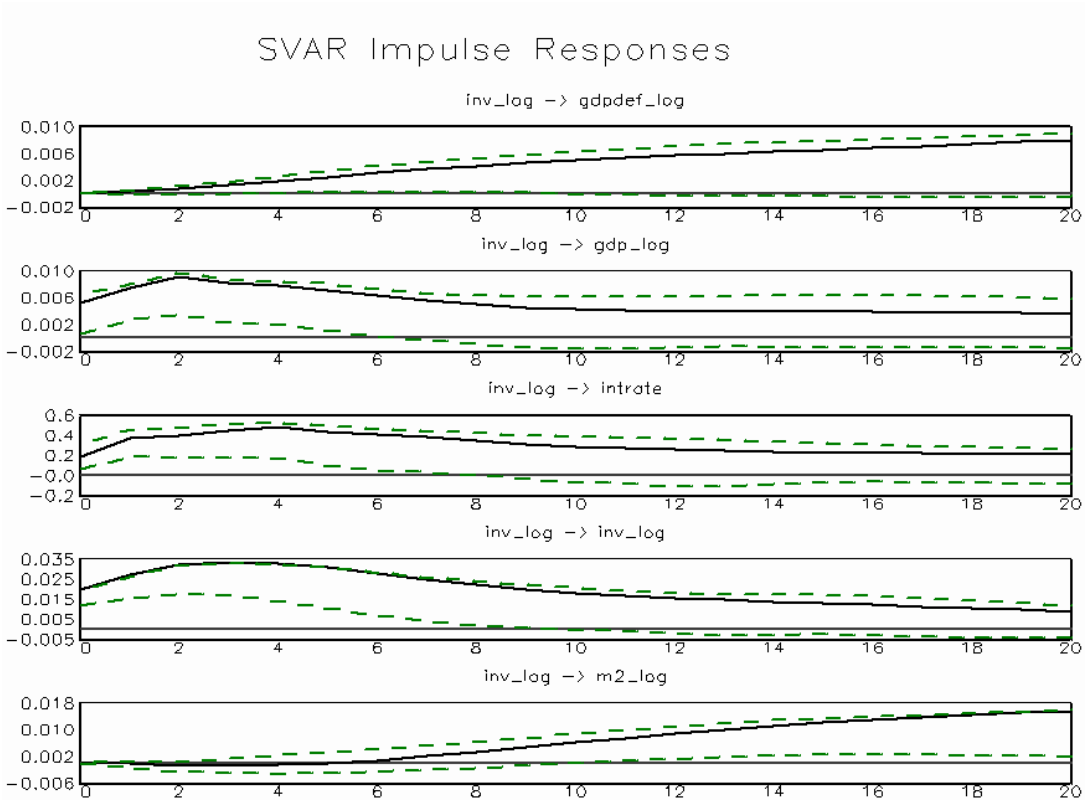
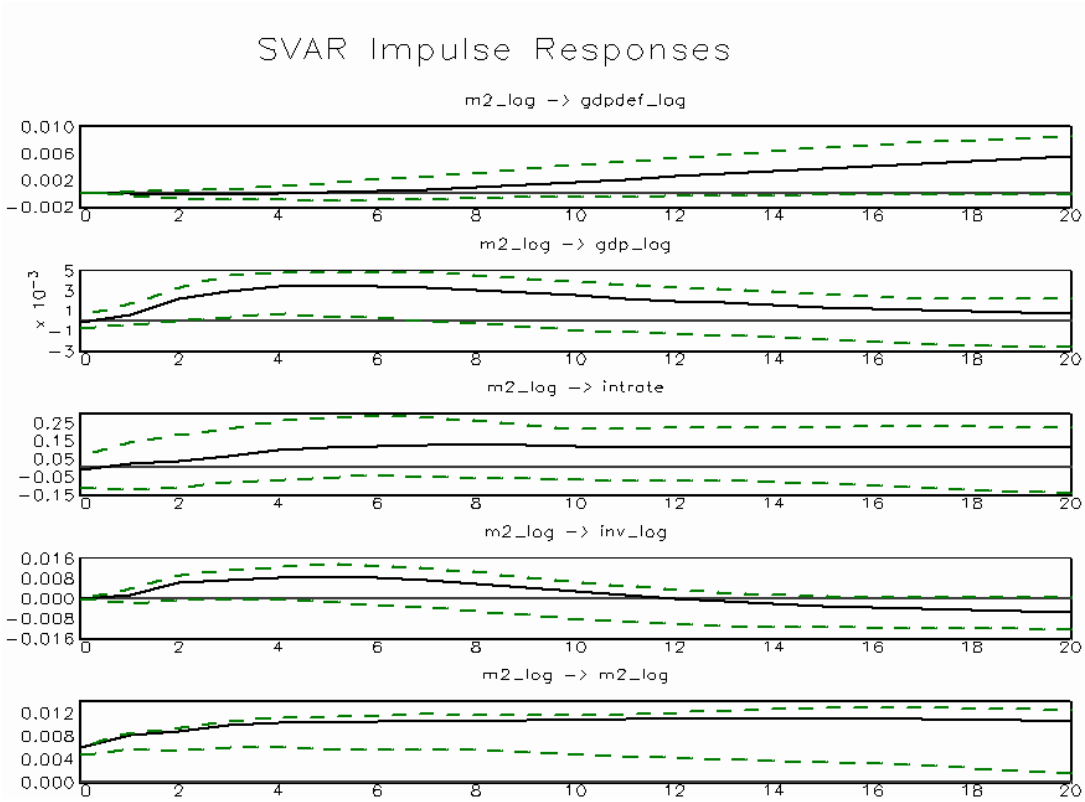


Figure 3.13: Response to money supply shock in SVAR model, Specification 1



not respond at all, GDP responds positively, but its response is weaker than in the case of reduced-form VAR and interest rate and money stock responds positively.

The response of the system to money supply shock depicted by the figure 3.13 again demonstrates that SVAR impulse responses of the specification 1 do not differ from reduced-form VAR impulse responses so much. Price level does not respond, GDP responds positively (transitory increase) and interest rate does not respond as in the case of reduced-form VAR. The only difference is that investment does not respond in the case of SVAR whilst it responds positively (transitory increase) in the case of reduced-form VAR. It indicates that the Post Keynesian framework finds investment more exogenous variable than it stems from reduced-form VAR model.

The response to GDP shock yields a different picture. Any variable does not significantly respond to GDP shock in the case of SVAR model whilst GDP,

Figure 3.14: Response to GDP shock in SVAR model, Specification 1

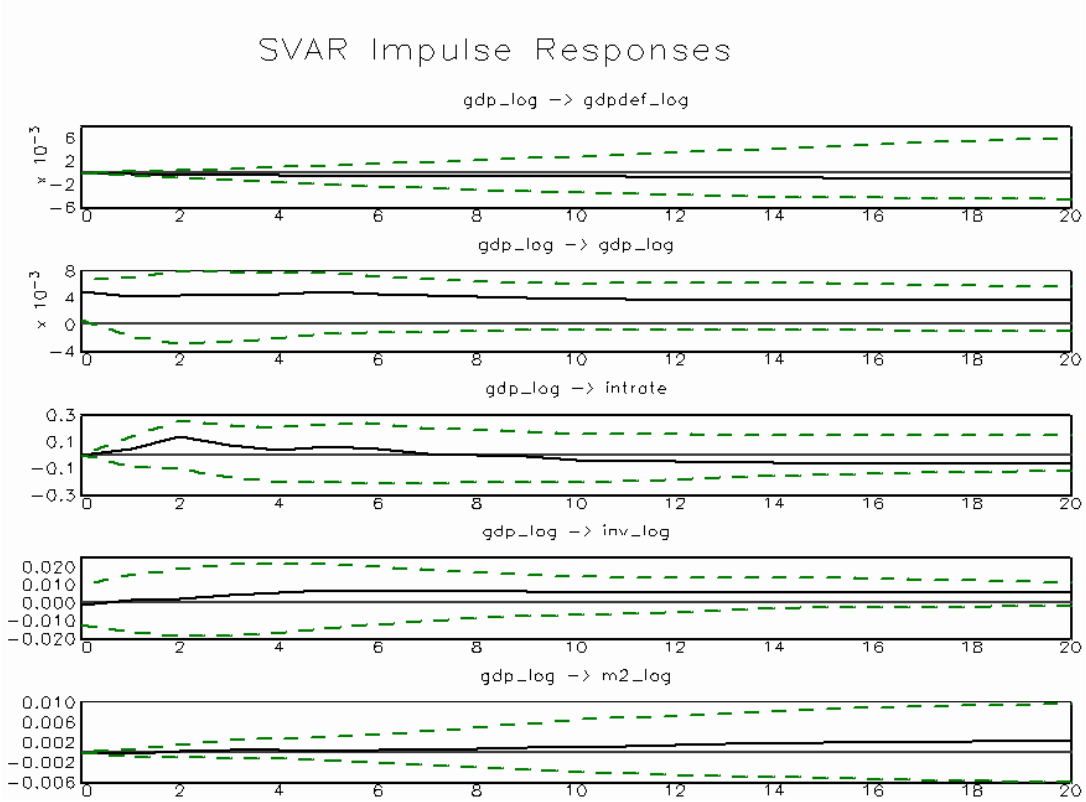
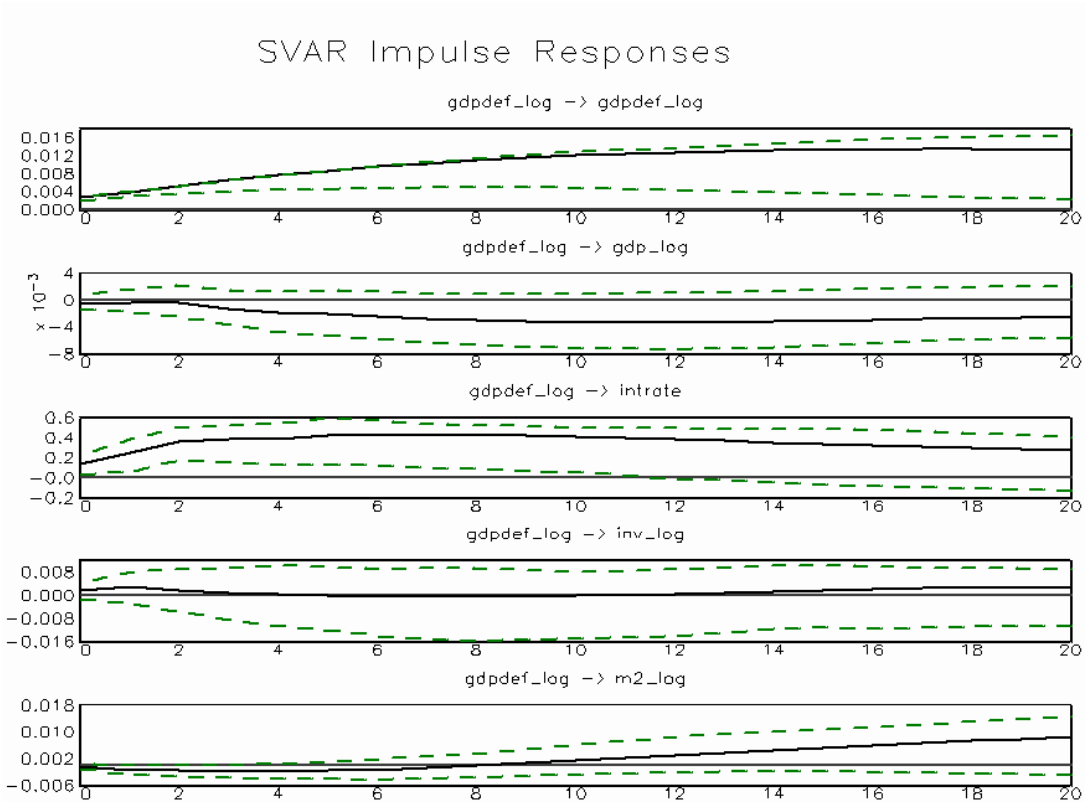


Figure 3.15: Response to GDP deflator shock in SVAR model, Specification 1



interest rate, investment and money stock responds positively in the case of reduced-form VAR. This is the only disadvantage of the Post Keynesian model. However, GDP shock is not the most important one in the analysis of business cycles dynamics.

The response to GDP deflator shock in SVAR model yields the same results as in the case of reduced-form VAR, i.e. no response of GDP, increase of interest rate and no response of investment and M2.

Let us investigate the dynamic behavior of the SVAR system by means of FEVD now. The figure 3.16 shows that significant variation of GDP in the long run and short run is caused by investment. It is different from what we found in the case of reduced-form VAR, where fluctuations of GDP were caused by themselves. It confirms that investment shocks are the main cause of business cycles fluctuations within the Post Keynesian framework.

The influence of interest rate on GDP fluctuations is also important, espe-

Figure 3.16: FEVD of GDP in SVAR model, Specification 1

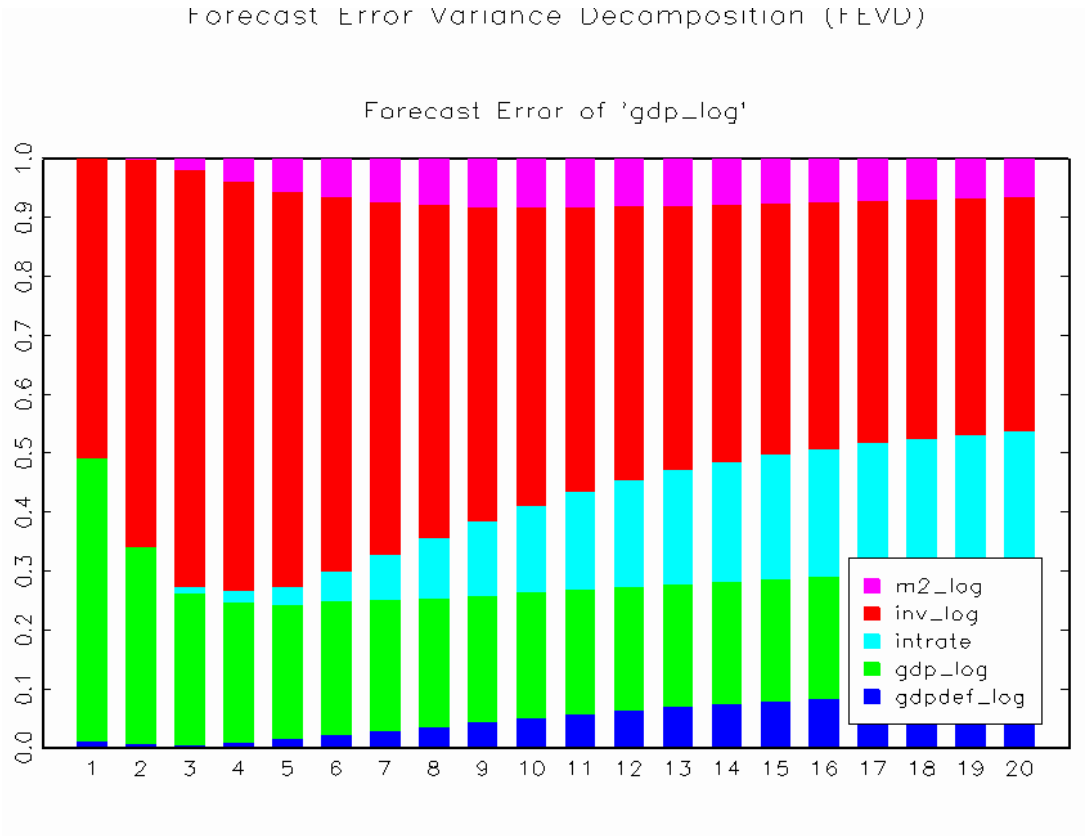
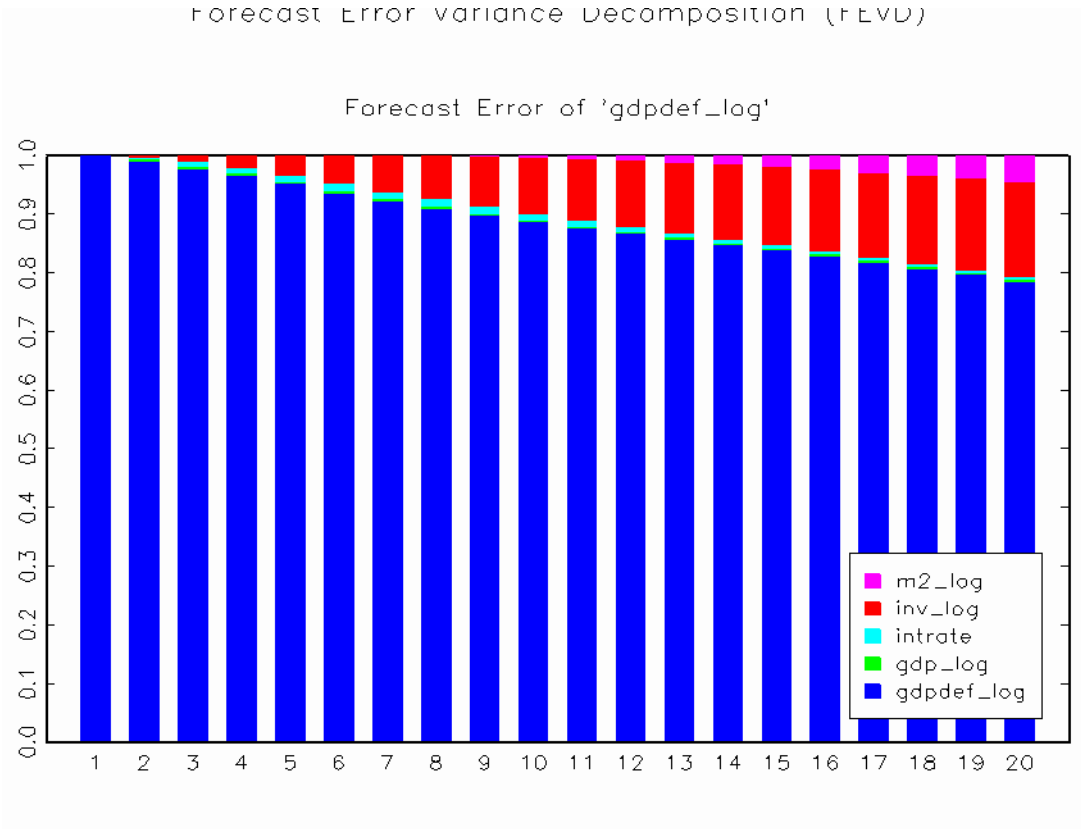


Figure 3.17: FEVD of GDP deflator in SVAR model, Specification 1



cially in the long run. It shows that monetary policy based on interest rates manipulations affects GDP but not price level (see later). That is why, Post Keynesian economists do not recommend using monetary policy to reduce inflation.

Influence of other variables (GDP deflator, M2) on GDP fluctuations is negligible.

As in the case of reduced-form VAR, fluctuations of price level are caused namely by themselves (see the figure 3.17). Only investment significantly influences fluctuations of price level in the long run what again confirms the importance of investment within the Post Keynesian framework.

The figure 3.18 shows relatively surprising evidence. M2 is less endogenous within the Post Keynesian model than what indicates reduced-form VAR. This FEVD analysis neglects transactional demand for money, since fluctuations of M2 do not depend on GDP. On the other hand, it confirms financial demand for money, since fluctuations of M2 are significantly dependent on investment

Figure 3.18: FEVD of M2 in SVAR model, Specification 1

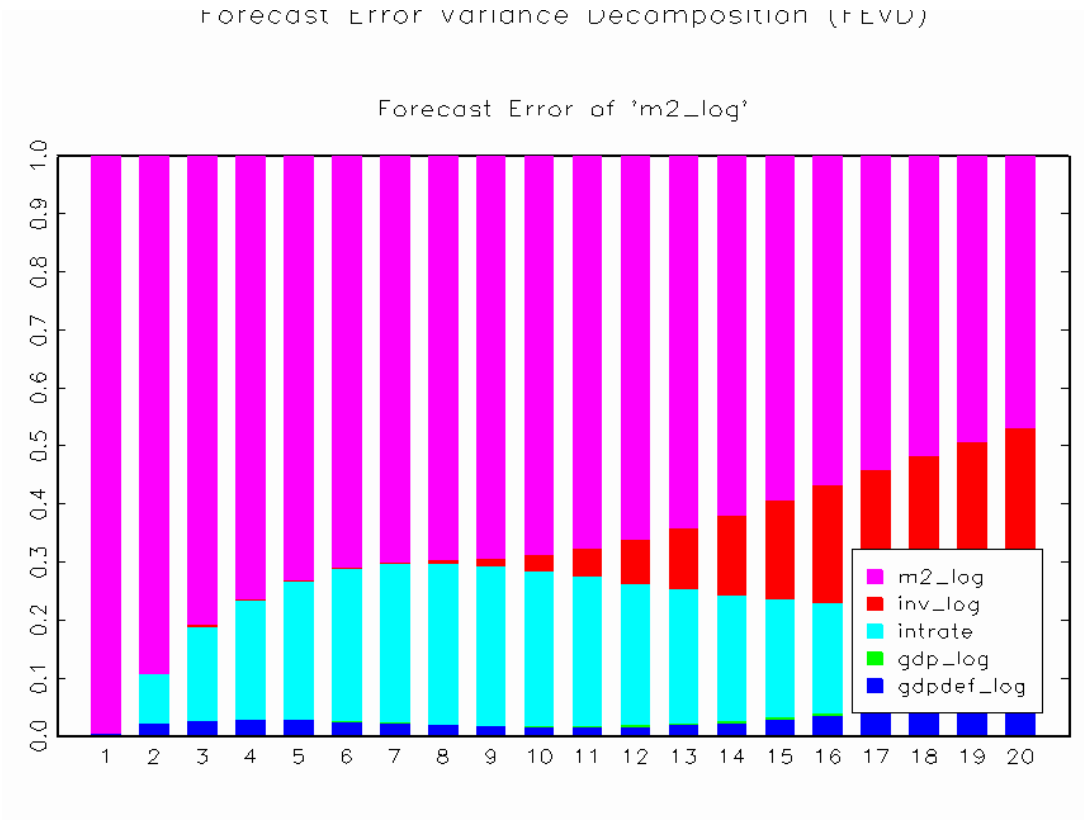
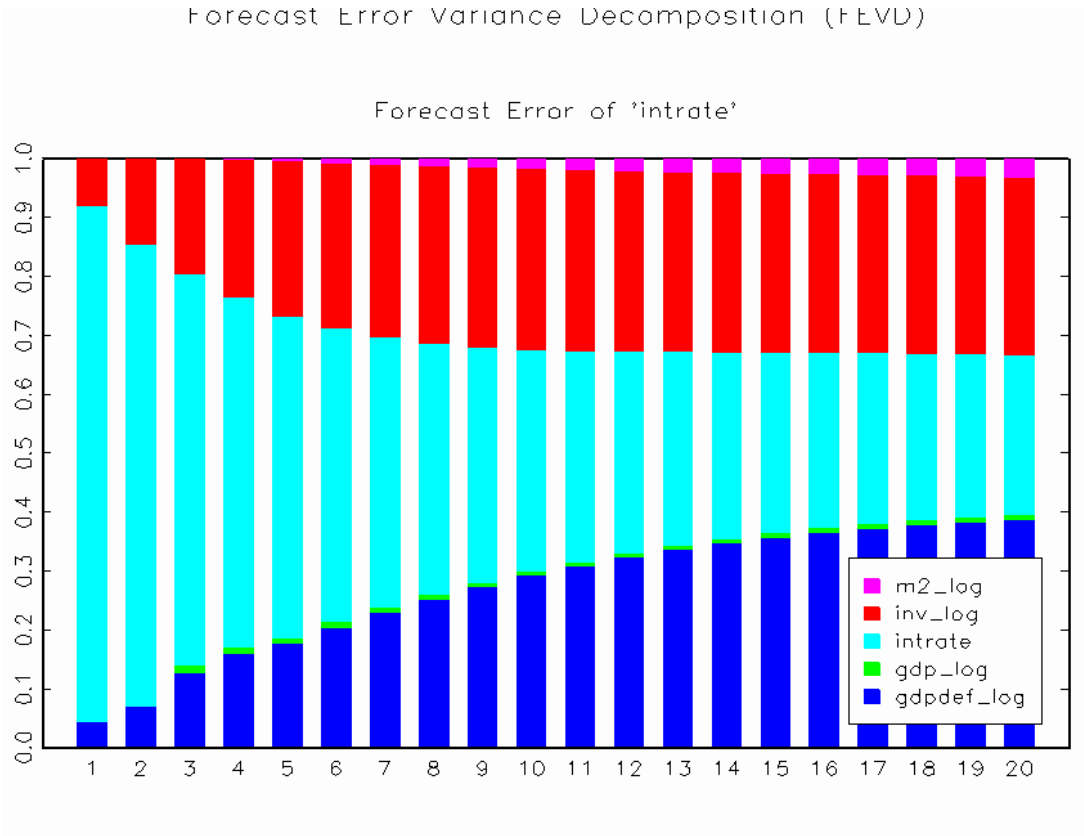


Figure 3.19: FEVD of interest rate in SVAR model, Specification 1

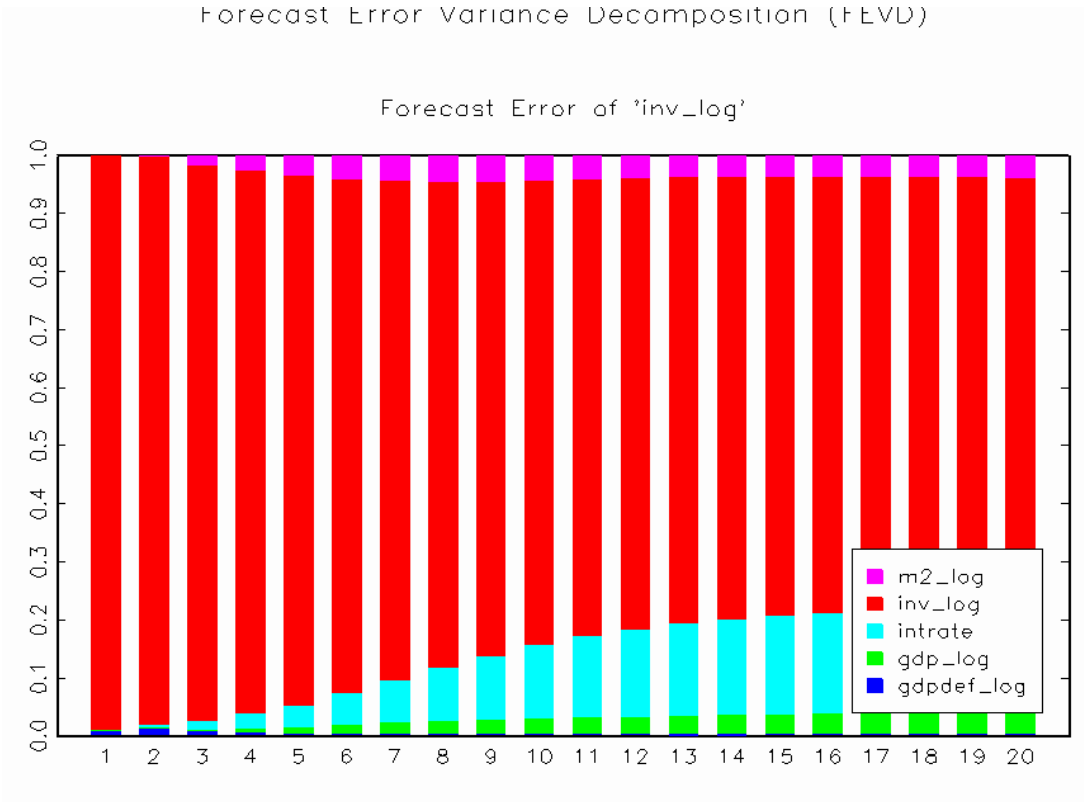


what is in line with the Post Keynesian ideas.

The FEVD of interest rate in SVAR model (see the figure 3.19) exhibits similar pattern as in the case of reduced-form VAR, i.e. interest rate is exogenous in the short run, but endogenous in the long run.

Last but not least, the figure 3.20 demonstrates that investment is very exogenous what confirms its importance in the Post Keynesian model.

Figure 3.20: FEVD of investment in SVAR model, Specification 1



3.2.2 Specification 2 (Model with vertical supply of money - the Monetarist model)

The Monetarist model can be expressed as follows in matrix form

$$\begin{pmatrix} 1 & -\alpha_{12} & -\alpha_{13} & -\alpha_{14} & -\alpha_{15} \\ 0 & 1 & 0 & -\alpha_{24} & 0 \\ 0 & -\alpha_{32} & 1 & 0 & -\alpha_{35} \\ 0 & -\alpha_{42} & -\alpha_{43} & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \log P_t \\ \log Y_t \\ r_t \\ \log I_t \\ \log M_t \end{pmatrix} = \begin{pmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \\ u_{4t} \\ u_{5t} \end{pmatrix}$$

or in structural equations

$$\log P_t = \alpha_{12} \log Y_t + \alpha_{13} r_t + \alpha_{14} \log I_t + \alpha_{15} \log M_t + u_{1t} \tag{3.6}$$

$$\log Y_t = \alpha_{24} \log I_t + u_{2t} \tag{3.7}$$

$$r_t = \alpha_{32} \log Y_t + \alpha_{42} \log M_t + u_{3t} \tag{3.8}$$

$$\log I_t = \alpha_{42} \log Y_t + \alpha_{43} r_t + u_{4t} \tag{3.9}$$

$$\log M_t = u_{5t} \tag{3.10}$$

The equations (3.6), (3.7) and (3.9) are the same as in the model with horizontal supply of money. What is different is supply of and demand for money. Supply of money represented by the equation (3.10) is vertical, since amount of money is determined by wishes of monetary authority and does not depend upon other endogenous variables according to Monetarists. Demand for money represented by the equation (3.8) depends upon GDP and money stock (it is inverse demand).

The figure 3.21 depicts the response of the Monetarist system to interest rate shock. Results are very different from what we found in the case of reduced-form VAR, since no variable significantly responds to interest rate shock. This confirms that the model with vertical supply of money hardly fits business cycles data.

Responses to money supply shock depicted by the figure 3.22 do not differ from reduced-form VAR responses much. The only two differences are mild positive response of price level and longer response of GDP (rise of GDP takes 7 quarters in the case of Monetarist SVAR model and only 4 quarters in the case of reduced-form VAR). The other responses are similar. It is in line with

Figure 3.21: Response to interest rate shock in SVAR model, Specification 2

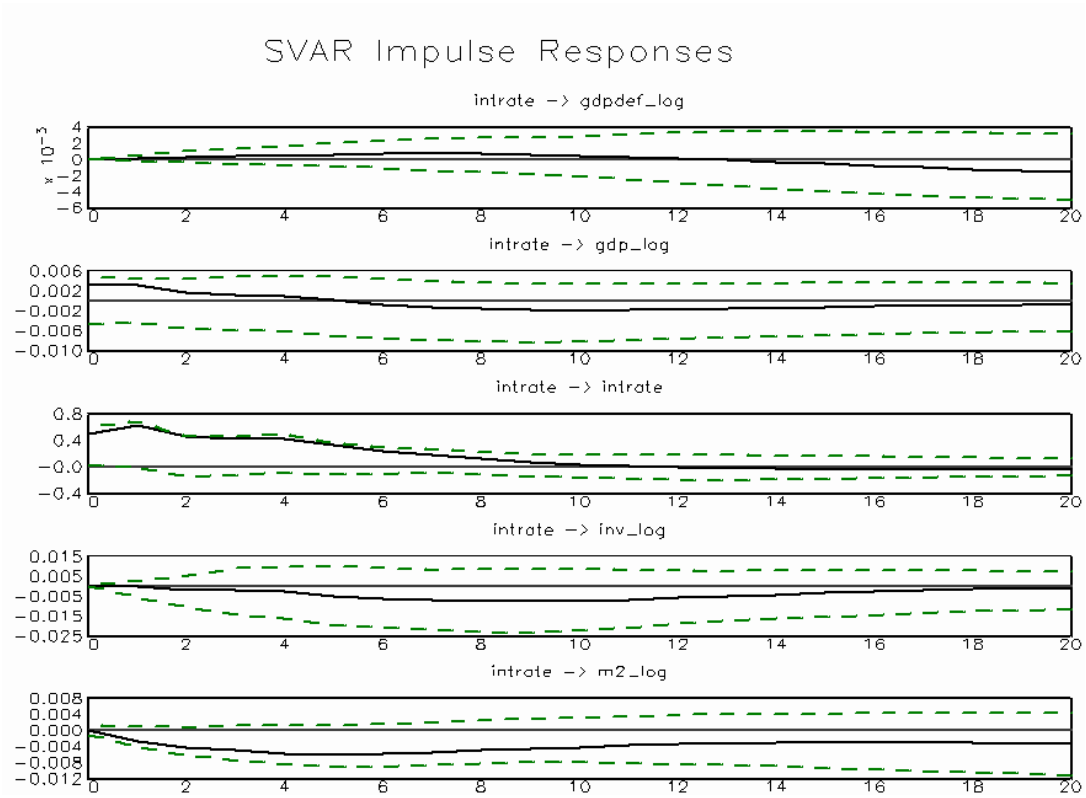


Figure 3.22: Response to money supply shock in SVAR model, Specification 2

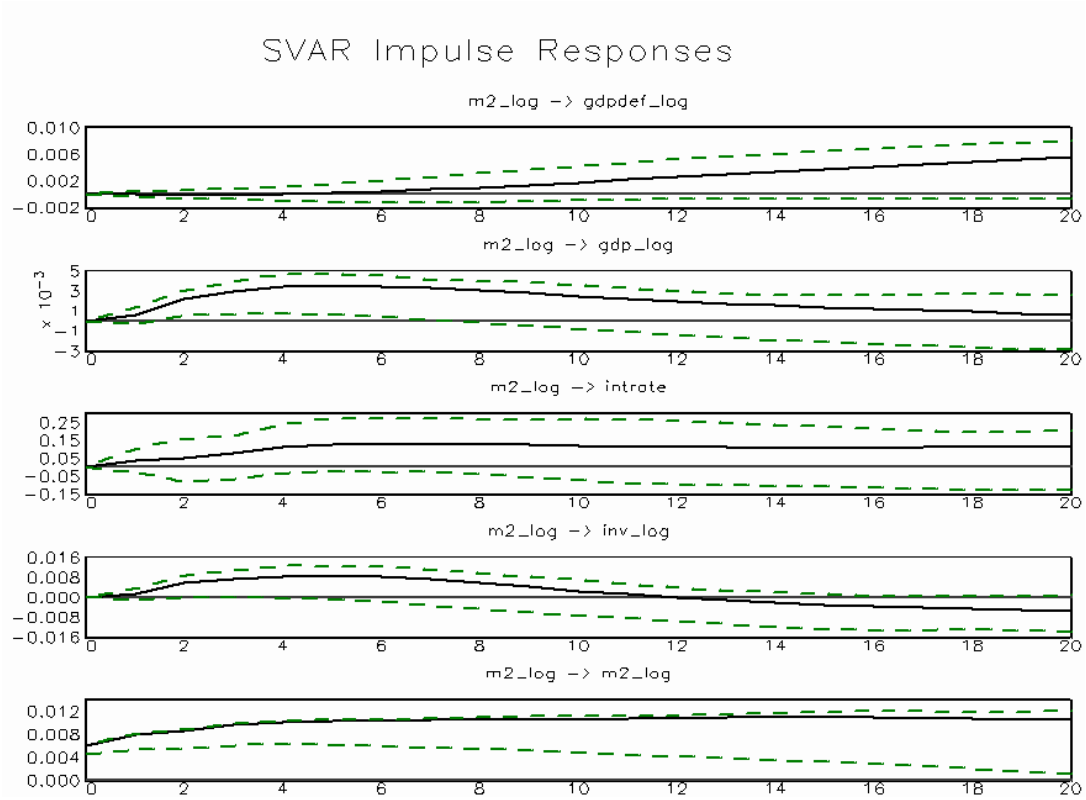
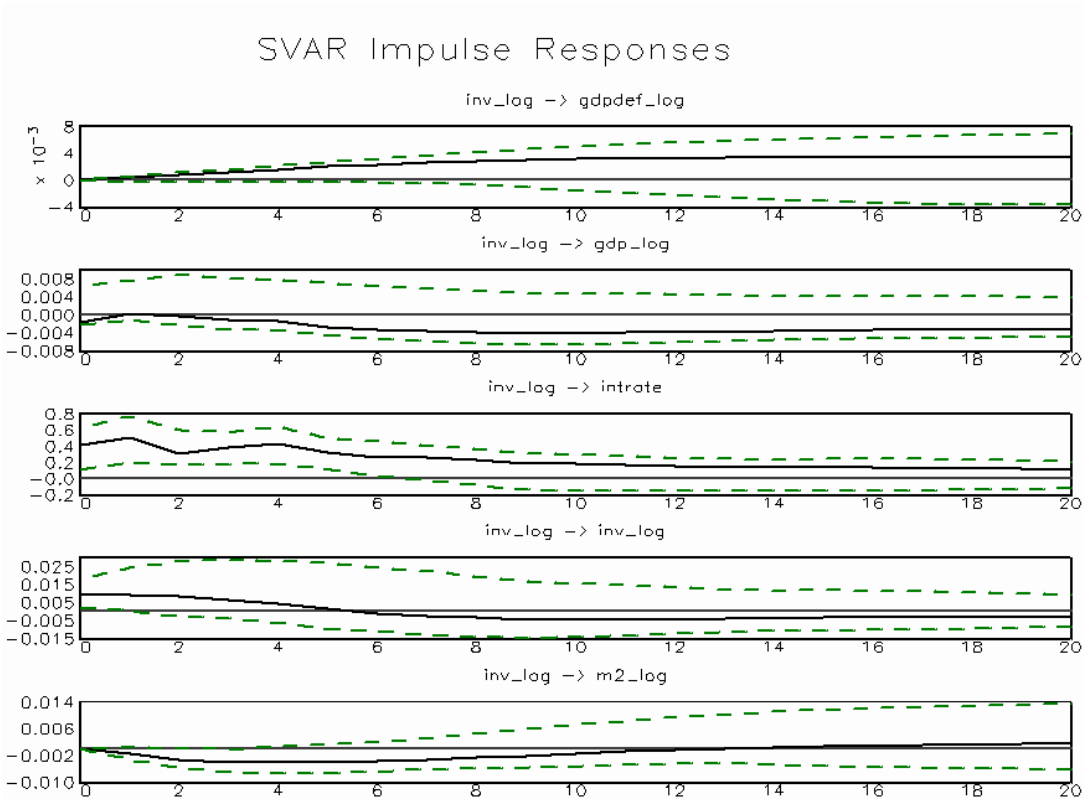


Figure 3.23: Response to investment shock in SVAR model, Specification 2



the Monetarist theory which contends that rise of nominal income is caused by rise of money supply.

The Monetarist model gives bad prediction also in the case of investment shock (see the figure 3.23). There is no response of GDP but rise of interest rate what can be interpreted as ineffectiveness of fiscal policy. Positive investment shock (expansive fiscal policy) leads to immediate rise of interest rate and no response of GDP according to Monetarists. So results of SVAR estimation are in line with the Monetarist theory but they are not consistent with empirical observations (see reduced-from VAR model).

This crowding-out effect can be most easily demonstrated by the IS-LM model (see the figure 3.24). The LM curve is vertical according to Monetarists. Therefore, upward shift of the IS curve (expansive fiscal policy) will result in rise of interest rate but not in rise of GDP.

No variable significantly responds to GDP shock in the Monetarist model.

Figure 3.24: IS-LM model, the Monetarist case

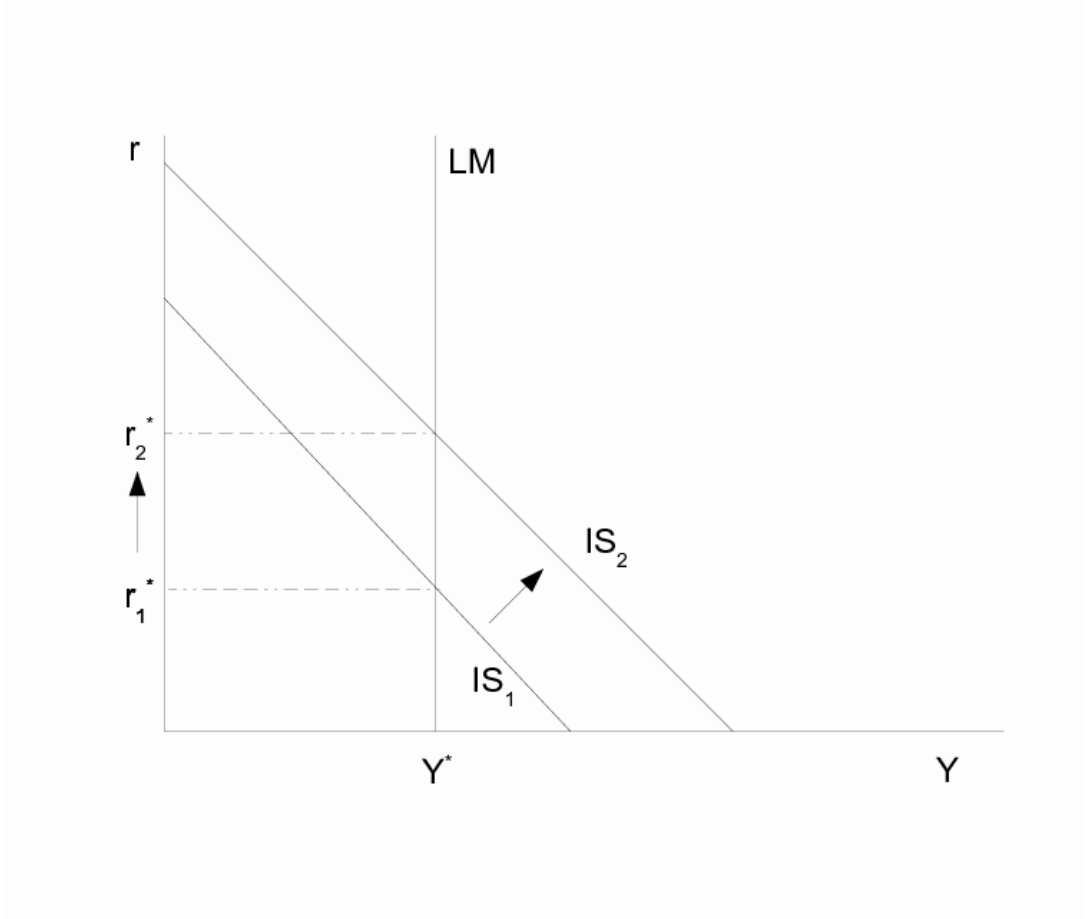


Figure 3.25: Response to GDP shock in SVAR model, Specification 2

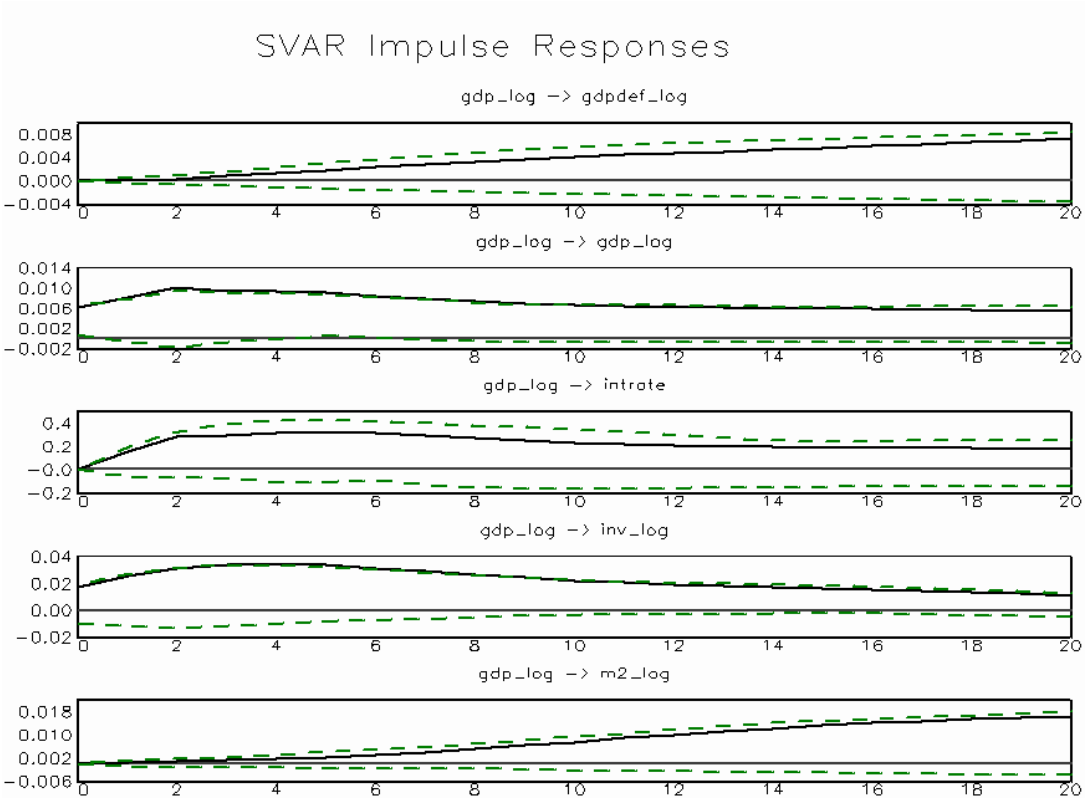
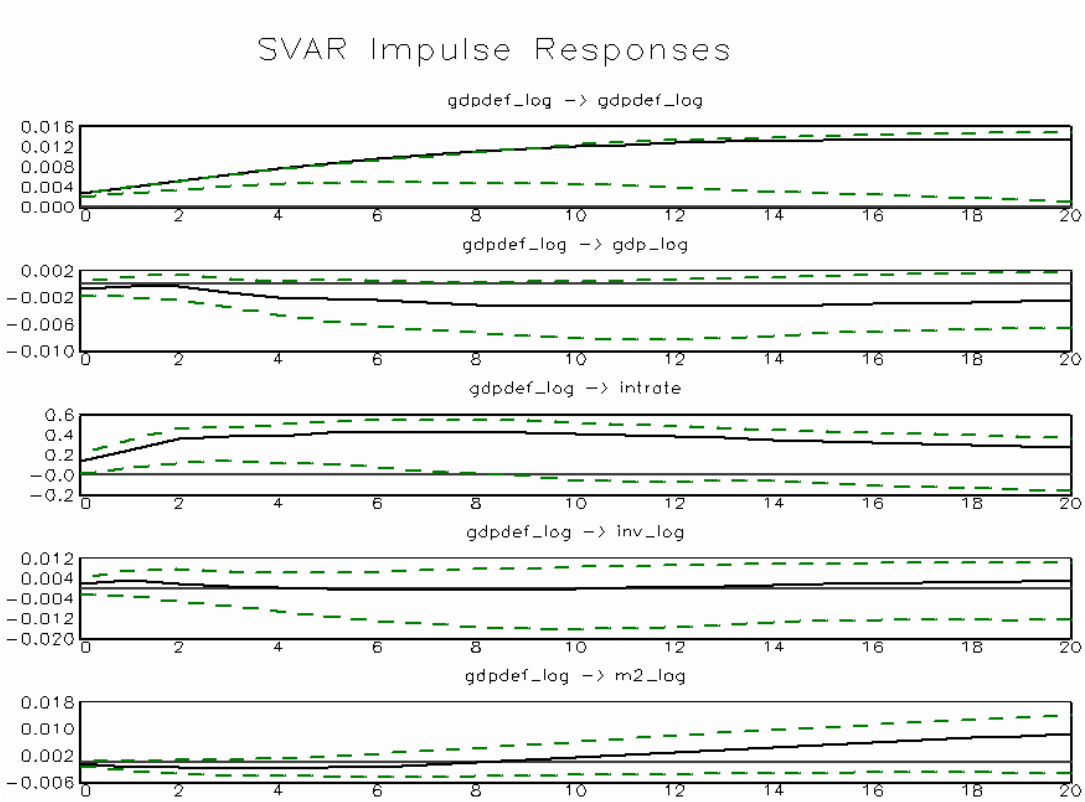


Figure 3.26: Response to GDP deflator shock in SVAR model, Specification 2



However, interest rate, investment and M2 respond positively in reduced-form VAR model. This is the same picture as in the case of the Post Keynesian model. The reason is most probably the SVAR specification.

Last but not least, GDP deflator shock gives similar results as in the case of reduced-form VAR.

Let us investigate the Monetarist model by means of FEVD now. The figure 3.27 shows that GDP is very exogenous in the Monetarist model as well. It is surprising that investment has greater weight in the long run than M2 what is not in line with the Monetarist theory.

The figure 3.28 offers similar picture as reduced-form VAR model. GDP deflator is very exogenous variable and contribution of other variables is negligible. One would expect greater weight of M2 in the case of the Monetarist model.

Figure 3.27: FEVD of GDP in SVAR model, Specification 2

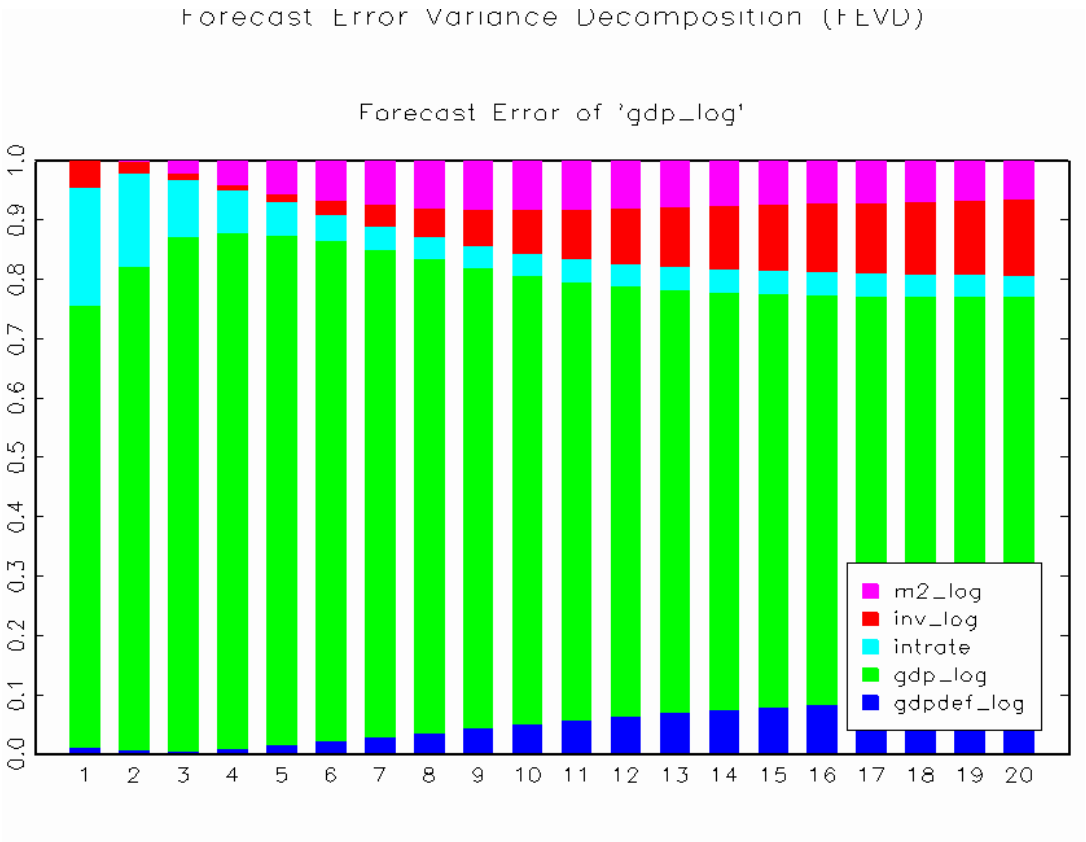


Figure 3.28: FEVD of GDP deflator in SVAR model, Specification 2

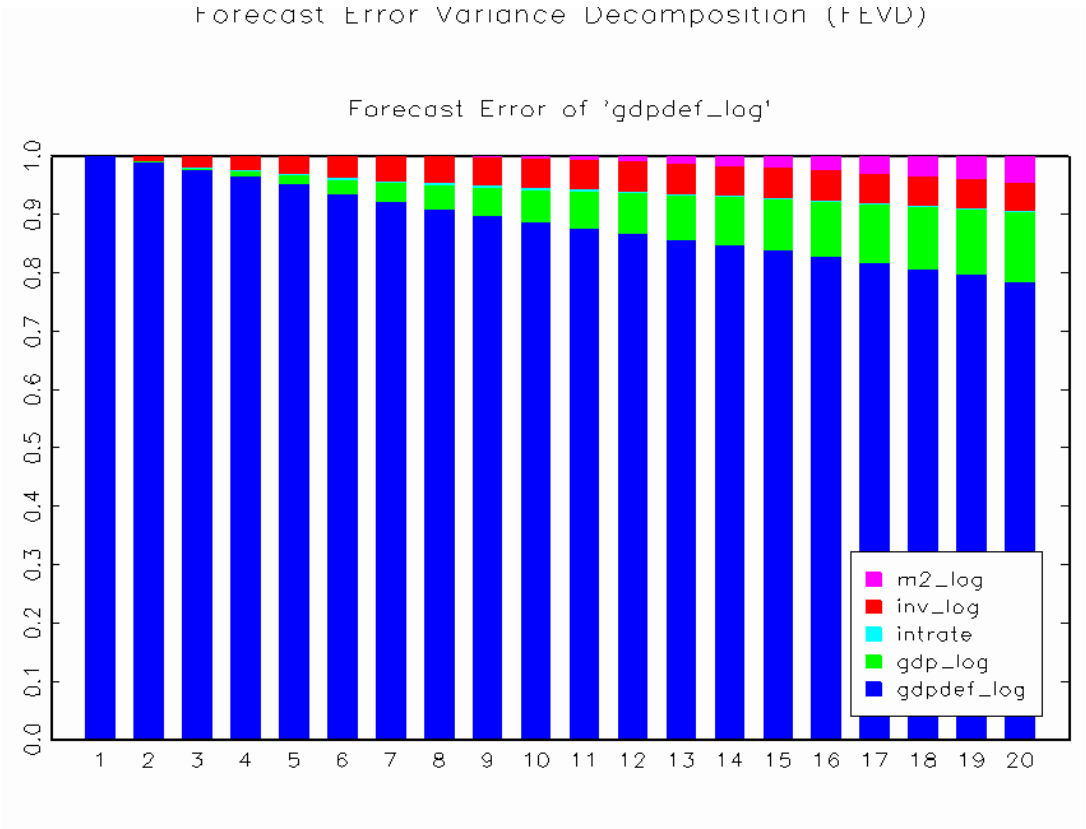


Figure 3.29: FEVD of M2 in SVAR model, Specification 2

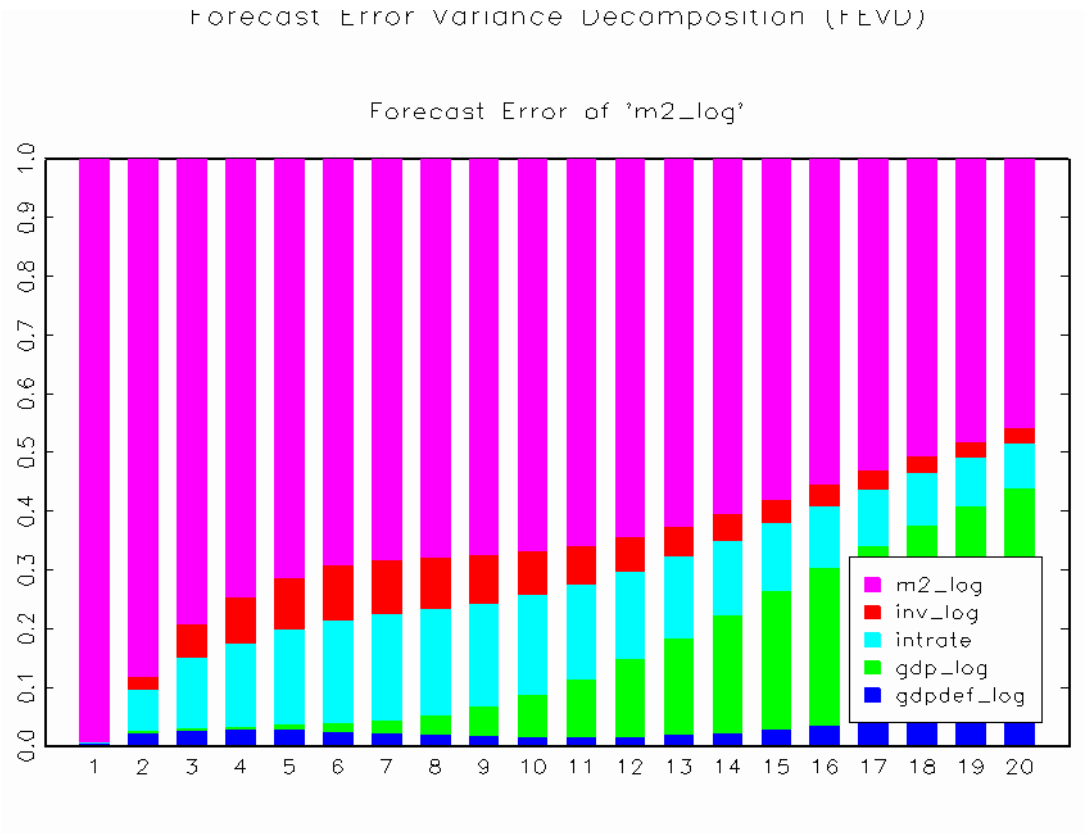
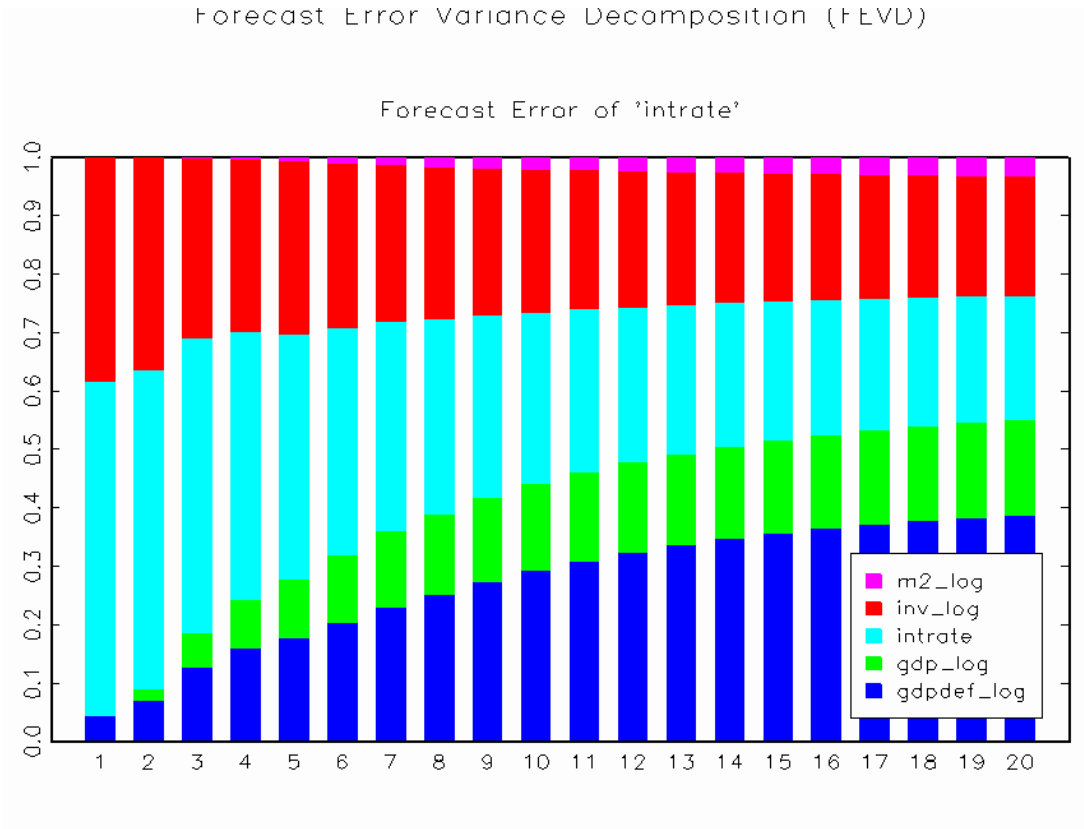


Figure 3.30: FEVD of interest rate in SVAR model, Specification 2

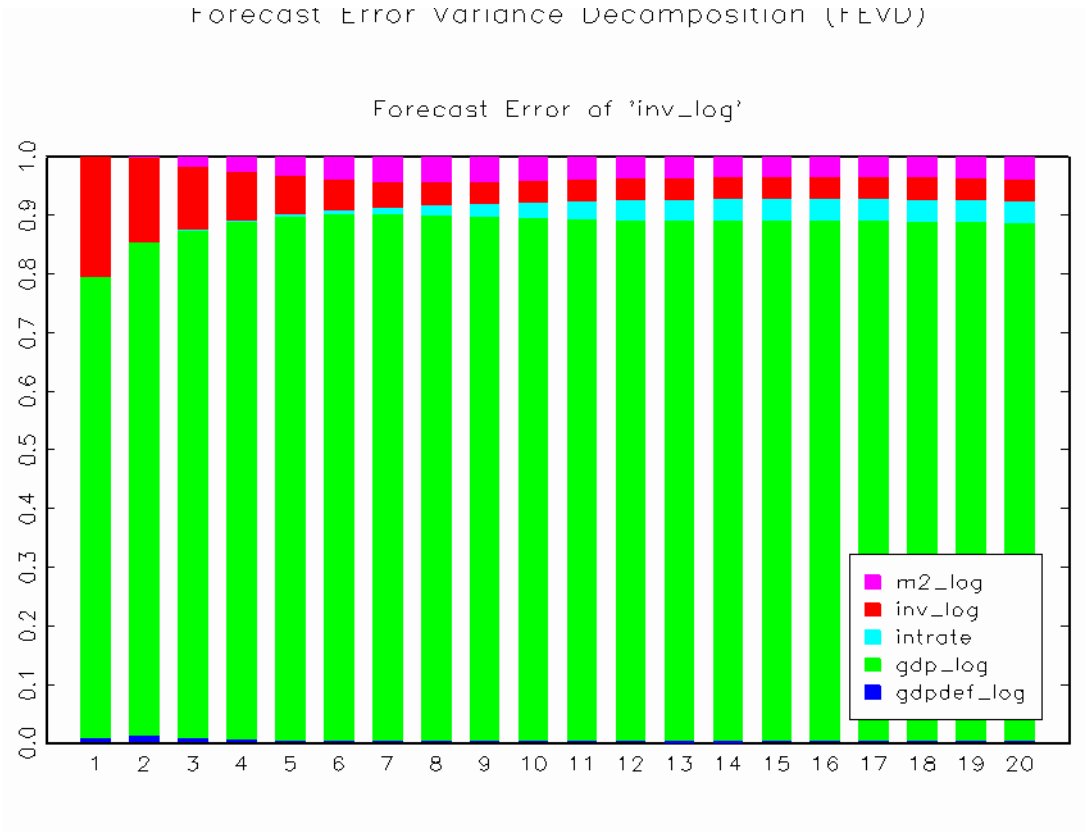


The figure 3.29 shows a surprising result. Even with vertical supply of money, 37% of fluctuations of M2 in the long run is caused by GDP. This is maybe due to instability of demand for money in time.

Interest rate is more endogenous within the Monetarist model than in reduced-form VAR (see the figure 3.30). This implies from logic of the Monetarist model. Central bank controls stock of money and interest rate is determined by demand for money and demand for money depends on GDP and investment.

Last but not least, fluctuations of investment are driven by fluctuations of GDP (see the figure 3.31), i.e. investment is endogenous in the Monetarist model whilst it is exogenous in the Post Keynesian model.

Figure 3.31: FEVD of investment in SVAR model, Specification 2



Chapter 4

Conclusion

What is the answer to our fundamental question? What causes business cycles fluctuations? Interest rate shocks together with nominal rigidities as the New Keynesian economics asserts or investment shocks together with endogeneity of money as the Post Keynesian economics asserts? Unfortunately, our results do not enable us to draw a straightforward conclusion.

Results indicate that: Money is endogenous in the long run but not in the short run, interest rate is exogenous (under the control of central bank) in the short run but not in the long run. Impulse-response analysis indicates that GDP significantly responds to interest rate shock what seems to support the New Keynesian hypothesis. On the other hand, this hypothesis is not supported by FEVD analysis. Only 20% of variation in GDP is caused by interest rates in the long run and even less in the short run. Impulse-response analysis also indicates that GDP significantly responds to investment shock what seems to support the Post Keynesian. However, this is neither confirmed by FEVD analysis. This is a little bit puzzle. Different tools yield different results.

Very strong inertia of inflation was found, even stronger than in Christiano *et al.* (2005). Price level responds neither to interest rate shock nor to investment shock nor to money supply shock. Nominal rigidities can be one possible explanation for such a strong inertia. It supports the New Keynesian hypothesis.

When two models, one with horizontal supply of money (the Post Keynesian model) and the other with vertical supply of money (monetarist model), are calibrated, impulse-response and FEVD analysis show that the Post Keynesian model fits business cycles data better than the monetarist model. Therefore, this thesis confirms Tobin (1970) theoretical findings that the "ultra-

Keynesian"model better explains observed stylized facts than the monetarist model. Unfortunately, the model with upward sloping supply of money which is more close to reality than other two models is not identified.

To summarize results, author's opinion based on results of empirical tests is that both phenomena (endogeneity of money and nominal rigidities) play role in generating business cycles fluctuations. It is hard to say what phenomenon dominates. It is necessary to admit that empirical analysis used in this thesis has weaknesses, because VAR model contains only 5 variables what could influence results. Author's effort was to keep the model manageably small. Some aspects of this topic are still unexplained. Therefore, this topic is worth of future research.

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Appendix A

JMulti output

A.1 Reduced-form VAR model

A.1.1 Results of estimation

```
VAR ESTIMATION RESULTS
endogenous variables:     gdpdef_log gdp_log intrate inv_log m2_log
exogenous variables:
deterministic variables:  CONST
endogenous lags:          4
exogenous lags:           0
sample range:             [1959 Q1, 2009 Q4], T = 200

modulus of the eigenvalues of the reverse characteristic polynomial :
|z| = ( 1.6842     1.6842     1.4250     1.4250     1.8608     1.8608
   2.2359     2.2359     1.6601     1.6601     1.2896     1.2896
    1.9766     1.9766     1.1949     1.0431     1.0431     1.0485
    1.0485     1.0045     )
Legend:
=======
              Equation 1   Equation 2  ...
-----------------------------------------
Variable 1 | Coefficient          ...
           | (Std. Dev.)
           | {p - Value}
           | [t - Value]
Variable 2 |         ...
```

```
...
-----------------------------------------


Lagged endogenous term:
=======================
                gdpdef_log   gdp_log   intrate   inv_log    m2_log
-------------------------------------------------------------------
gdpdef_log(t-1)|    1.429    -0.006    32.484     0.743    -0.167
               |   (0.076)   (0.204)  (18.669)   (0.560)   (0.172)
               |   {0.000}   {0.976}   {0.082}   {0.185}   {0.331}
               |  [18.875]  [-0.030]   [1.740]   [1.327]  [-0.972]
gdp_log   (t-1)|   -0.048     0.867    10.871     0.520    -0.030
               |   (0.036)   (0.098)   (8.947)   (0.269)   (0.082)
               |   {0.188}   {0.000}   {0.224}   {0.053}   {0.714}
               |  [-1.317]   [8.858]   [1.215]   [1.936]  [-0.367]
intrate   (t-1)|    0.000     0.001     1.170    -0.004    -0.005
               |   (0.000)   (0.001)   (0.077)   (0.002)   (0.001)
               |   {0.165}   {0.434}   {0.000}   {0.115}   {0.000}
               |   [1.387]   [0.782]  [15.278]  [-1.575]  [-7.128]
inv_log   (t-1)|    0.026     0.151     4.769     1.294     0.044
               |   (0.014)   (0.037)   (3.391)   (0.102)   (0.031)
               |   {0.061}   {0.000}   {0.160}   {0.000}   {0.156}
               |   [1.874]   [4.059]   [1.407]  [12.720]   [1.419]
m2_log    (t-1)|    0.000     0.107     6.268     0.247     1.326
               |   (0.032)   (0.086)   (7.838)   (0.235)   (0.072)
               |   {0.998}   {0.214}   {0.424}   {0.293}   {0.000}
               |   [0.002]   [1.243]   [0.800]   [1.052]  [18.380]
gdpdef_log(t-2)|   -0.263    -0.021    15.698    -1.400     0.546
               |   (0.132)   (0.356)  (32.509)   (0.976)   (0.299)
               |   {0.046}   {0.954}   {0.629}   {0.151}   {0.068}
               |  [-1.993]  [-0.058]   [0.483]  [-1.435]   [1.825]
gdp_log   (t-2)|    0.018     0.088     6.229    -0.293     0.114
               |   (0.044)   (0.120)  (10.951)   (0.329)   (0.101)
               |   {0.691}   {0.461}   {0.570}   {0.373}   {0.260}
               |   [0.397]   [0.738]   [0.569]  [-0.891]   [1.127]
intrate   (t-2)|    0.000    -0.003    -0.596     0.001     0.004
```

```
                |   (0.000)   (0.001)   (0.114)   (0.003)   (0.001)
                |   {0.768}   {0.042}   {0.000}   {0.873}   {0.000}
                |  [-0.295]  [-2.034]  [-5.227]   [0.160]   [4.280]
inv_log    (t-2)|   -0.018    -0.086    -8.914    -0.255    -0.052
                |   (0.019)   (0.052)   (4.768)   (0.143)   (0.044)
                |   {0.360}   {0.100}   {0.062}   {0.075}   {0.239}
                |  [-0.915]  [-1.644]  [-1.869]  [-1.781]  [-1.178]
m2_log     (t-2)|   -0.022     0.088    -9.714     0.323    -0.305
                |   (0.053)   (0.144)  (13.151)   (0.395)   (0.121)
                |   {0.682}   {0.539}   {0.460}   {0.413}   {0.012}
                |  [-0.410]   [0.615]  [-0.739]   [0.819]  [-2.519]
gdpdef_log(t-3)|    0.055    -0.138   -76.985     1.030    -0.105
                |   (0.135)   (0.363)  (33.193)   (0.996)   (0.305)
                |   {0.683}   {0.704}   {0.020}   {0.301}   {0.731}
                |   [0.408]  [-0.380]  [-2.319]   [1.034]  [-0.343]
gdp_log    (t-3)|    0.039    -0.004   -22.800     0.241     0.087
                |   (0.043)   (0.117)  (10.701)   (0.321)   (0.098)
                |   {0.373}   {0.975}   {0.033}   {0.452}   {0.375}
                |   [0.892]  [-0.032]  [-2.131]   [1.751]   [0.888]
intrate    (t-3)|    0.000     0.003     0.576     0.006    -0.002
                |   (0.000)   (0.001)   (0.117)   (0.004)   (0.001)
                |   {0.564}   {0.010}   {0.000}   {0.108}   {0.059}
                |  [-0.577]   [2.593]   [4.913]   [1.607]  [-1.887]
inv_log    (t-3)|   -0.001    -0.137     6.307    -0.215    -0.005
                |   (0.019)   (0.052)   (4.747)   (0.142)   (0.044)
                |   {0.972}   {0.008}   {0.184}   {0.131}   {0.905}
                |  [-0.035]  [-2.638]   [1.329]  [-1.509]  [-0.119]
m2_log     (t-3)|    0.029    -0.227     4.466    -0.905     0.085
                |   (0.052)   (0.141)  (12.871)   (0.386)   (0.118)
                |   {0.574}   {0.107}   {0.729}   {0.019}   {0.475}
                |   [0.562]  [-1.611]   [0.347]  [-2.342]   [0.714]
gdpdef_log(t-4)|   -0.238     0.168    29.524    -0.278    -0.262
                |   (0.077)   (0.209)  (19.104)   (0.573)   (0.176)
                |   {0.002}   {0.422}   {0.122}   {0.628}   {0.136}
                |  [-3.069]   [0.802]   [1.545]  [-0.484]  [-1.491]
gdp_log    (t-4)|   -0.022     0.009     3.253    -0.350    -0.192
                |   (0.035)   (0.093)   (8.527)   (0.256)   (0.078)
```

```
                |   {0.531}   {0.923}   {0.703}   {0.171}   {0.014}
                |  [-0.627]   [0.097]   [0.381]  [-1.368]  [-2.445]
intrate    (t-4)|    0.000    -0.002    -0.269    -0.005     0.002
                |   (0.000)   (0.001)   (0.082)   (0.002)   (0.001)
                |   {0.581}   {0.014}   {0.001}   {0.048}   {0.001}
                |   [0.553]  [-2.462]  [-3.304]  [-1.977]   [3.185]
inv_log    (t-4)|   -0.002     0.078    -1.384     0.106     0.037
                |   (0.013)   (0.035)   (3.235)   (0.097)   (0.030)
                |   {0.872}   {0.028}   {0.669}   {0.275}   {0.208}
                |  [-0.161]   [2.201]  [-0.428]   [1.091]   [1.258]
m2_log     (t-4)|    0.005     0.044    -0.747     0.263    -0.119
                |   (0.030)   (0.082)   (7.473)   (0.224)   (0.069)
                |   {0.871}   {0.593}   {0.920}   {0.241}   {0.085}
                |   [0.162]   [0.535]  [-0.100]   [1.174]  [-1.725]
-------------------------------------------------------------------


Deterministic term:
===================
          gdpdef_log   gdp_log   intrate   inv_log    m2_log
-------------------------------------------------------------
CONST   |    0.051     0.218    11.301    -0.410     0.072
        |   (0.043)   (0.117)  (10.695)   (0.321)   (0.098)
        |   {0.238}   {0.062}   {0.291}   {0.201}   {0.462}
        |   [1.180]   [1.863]   [1.057]  [-1.278]   [0.735]
-------------------------------------------------------------

Log Likelihood:       2.775249e+03
Determinant (Cov):    6.093619e-19

Covariance:
 7.146064e-06 -1.779706e-06  3.627314e-04  4.314026e-06 -9.578535e-07
-1.779706e-06  5.196287e-05  8.579914e-04  9.400925e-05  5.040867e-06
 3.627314e-04  8.579914e-04  4.343523e-01  3.845220e-03  7.287593e-05
 4.314026e-06  9.400925e-05  3.845220e-03  3.911533e-04  2.119258e-05
-9.578535e-07  5.040867e-06  7.287593e-05  2.119258e-05  3.678980e-05
```

```
Correlation:
 1.000000e+00 -9.235667e-02  2.058878e-01  8.159729e-02 -5.907476e-02
-9.235667e-02  1.000000e+00  1.805990e-01  6.594024e-01  1.152909e-01
 2.058878e-01  1.805990e-01  1.000000e+00  2.950031e-01  1.823053e-02
 8.159729e-02  6.594024e-01  2.950031e-01  1.000000e+00  1.766634e-01
-5.907476e-02  1.152909e-01  1.823053e-02  1.766634e-01  1.000000e+00

AIC:         -4.089187e+01
FPE:          1.748121e-18
SC:          -3.916026e+01
HQ:          -4.019112e+01
```

A.1.2 FEVD

```
VAR FORECAST ERROR VARIANCE DECOMPOSITION OF GDP

Proportions of forecast error in "gdp_log"
                    accounted for by:
```

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.01	0.99	0.00	0.00	0.00
2	0.00	0.95	0.01	0.04	0.00
3	0.00	0.89	0.00	0.08	0.02
4	0.01	0.86	0.01	0.09	0.04
5	0.01	0.83	0.02	0.09	0.05
6	0.02	0.80	0.03	0.09	0.06
7	0.02	0.77	0.06	0.08	0.07
8	0.03	0.74	0.08	0.08	0.07
9	0.04	0.71	0.10	0.08	0.08
10	0.05	0.69	0.12	0.07	0.08
11	0.05	0.67	0.14	0.07	0.08
12	0.06	0.65	0.15	0.07	0.07
13	0.06	0.64	0.16	0.06	0.07
14	0.07	0.63	0.17	0.06	0.07
15	0.07	0.62	0.18	0.06	0.07
16	0.08	0.61	0.19	0.06	0.07
17	0.08	0.61	0.19	0.06	0.07

18	0.08	0.60	0.19	0.06	0.06
19	0.08	0.60	0.20	0.05	0.06
20	0.09	0.60	0.20	0.05	0.06

VAR FORECAST ERROR VARIANCE DECOMPOSITION OF GDP DEFLATOR

Proportions of forecast error in "gdpdef_log"
accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	1.00	0.00	0.00	0.00	0.00
2	0.99	0.00	0.01	0.01	0.00
3	0.98	0.00	0.01	0.01	0.00
4	0.97	0.00	0.01	0.02	0.00
5	0.95	0.01	0.02	0.02	0.00
6	0.93	0.01	0.02	0.03	0.00
7	0.92	0.02	0.02	0.04	0.00
8	0.91	0.03	0.02	0.04	0.00
9	0.89	0.03	0.02	0.05	0.00
10	0.88	0.04	0.02	0.06	0.00
11	0.87	0.04	0.02	0.06	0.01
12	0.86	0.04	0.02	0.07	0.01
13	0.84	0.05	0.02	0.07	0.01
14	0.83	0.05	0.02	0.08	0.02
15	0.82	0.05	0.02	0.09	0.02
16	0.81	0.06	0.01	0.09	0.02
17	0.80	0.06	0.01	0.10	0.03
18	0.79	0.06	0.01	0.10	0.03
19	0.77	0.07	0.01	0.11	0.04
20	0.76	0.07	0.01	0.12	0.04

VAR FORECAST ERROR VARIANCE DECOMPOSITION OF M2

Proportions of forecast error in "m2_log"

	accounted for by:				
forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.00	0.01	0.00	0.02	0.96
2	0.02	0.01	0.08	0.04	0.86
3	0.02	0.00	0.16	0.03	0.78
4	0.03	0.00	0.20	0.03	0.74
5	0.03	0.01	0.24	0.03	0.70
6	0.02	0.01	0.25	0.04	0.68
7	0.02	0.01	0.26	0.04	0.67
8	0.02	0.02	0.26	0.05	0.66
9	0.02	0.03	0.25	0.06	0.65
10	0.01	0.04	0.24	0.07	0.63
11	0.01	0.06	0.22	0.09	0.62
12	0.01	0.08	0.20	0.10	0.60
13	0.02	0.11	0.19	0.12	0.57
14	0.02	0.13	0.17	0.13	0.55
15	0.02	0.15	0.15	0.15	0.52
16	0.03	0.17	0.14	0.16	0.49
17	0.04	0.19	0.13	0.17	0.47
18	0.04	0.21	0.12	0.18	0.45
19	0.05	0.23	0.11	0.19	0.42
20	0.06	0.24	0.10	0.20	0.40

VAR FORECAST ERROR VARIANCE DECOMPOSITION OF INTEREST RATE

Proportions of forecast error in "intrate"

	accounted for by:				
forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.04	0.04	0.92	0.00	0.00
2	0.07	0.09	0.83	0.00	0.00
3	0.12	0.15	0.71	0.01	0.00
4	0.16	0.17	0.65	0.02	0.00
5	0.17	0.19	0.60	0.03	0.01
6	0.20	0.20	0.55	0.04	0.01
7	0.22	0.20	0.51	0.05	0.01

8	0.25	0.20	0.48	0.05	0.02
9	0.26	0.20	0.45	0.06	0.02
10	0.28	0.20	0.43	0.07	0.02
11	0.30	0.20	0.41	0.07	0.02
12	0.31	0.19	0.39	0.08	0.02
13	0.33	0.19	0.37	0.08	0.02
14	0.34	0.19	0.36	0.09	0.03
15	0.35	0.18	0.35	0.09	0.03
16	0.35	0.18	0.34	0.10	0.03
17	0.36	0.18	0.33	0.10	0.03
18	0.36	0.18	0.32	0.11	0.03
19	0.37	0.17	0.31	0.11	0.03
20	0.37	0.17	0.31	0.12	0.03

VAR FORECAST ERROR VARIANCE DECOMPOSITION OF INVESTMENT

Proportions of forecast error in "inv_log"
accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.01	0.45	0.02	0.52	0.00
2	0.01	0.51	0.01	0.47	0.00
3	0.01	0.52	0.01	0.45	0.02
4	0.00	0.54	0.01	0.43	0.02
5	0.00	0.55	0.01	0.40	0.03
6	0.00	0.56	0.02	0.38	0.04
7	0.00	0.56	0.03	0.37	0.04
8	0.00	0.55	0.04	0.36	0.04
9	0.00	0.55	0.06	0.35	0.04
10	0.00	0.55	0.07	0.34	0.04
11	0.00	0.55	0.08	0.34	0.04
12	0.00	0.54	0.09	0.33	0.04
13	0.00	0.54	0.09	0.33	0.03
14	0.00	0.54	0.10	0.32	0.03
15	0.00	0.54	0.10	0.32	0.03
16	0.00	0.54	0.11	0.32	0.03
17	0.00	0.55	0.11	0.31	0.03

18	0.00	0.55	0.11	0.31	0.03
19	0.00	0.55	0.11	0.30	0.04
20	0.00	0.55	0.11	0.30	0.04

A.2 SVAR model

A.2.1 Model with horizontal supply of money

```
This is a B-model

Step 1:
Obtaining starting values from decomposition of correlation matrix...
Iterations needed for correlation matrix decomposition:  14.0000
Vector of rescaled starting values:
  0.0027
 -0.0007
  0.1357
  0.0016
 -0.0004
  0.0050
 -0.0012
  0.6179
  0.0052
  0.1868
  0.0197
 -0.0001
 -0.0140
  0.0061

Step 2:
Structural VAR Estimation Results
ML Estimation, Scoring Algorithm (see Amisano & Giannini (1992))
Convergence after 1 iterations
Log Likelihood: 3635.3377
Structural VAR is over-identified with   1.0000  degrees of freedom
LR Test: Chi^2(  1.0000 ):   6.7679 , Prob:   0.0093
```

```
Estimated A matrix:
  1.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   1.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   1.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   1.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   1.0000

Estimated standard errors for A matrix:
  0.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   0.0000

Estimated B matrix:
  0.0027   0.0000   0.0000   0.0000   0.0000
 -0.0007   0.0050   0.0000   0.0052  -0.0001
  0.1357   0.0000   0.6179   0.1868  -0.0140
  0.0016  -0.0012   0.0000   0.0197   0.0000
 -0.0004   0.0000   0.0000   0.0000   0.0061

Estimated standard errors for B matrix
  0.0001   0.0000   0.0000   0.0000   0.0000
  0.0005   0.0012   0.0000   0.0013   0.0004
  0.0462   0.0000   0.0309   0.0447   0.0437
  0.0014   0.0046   0.0000   0.0010   0.0000
  0.0004   0.0000   0.0000   0.0000   0.0003

A^-1*B
  0.0027   0.0000   0.0000   0.0000   0.0000
 -0.0007   0.0050   0.0000   0.0052  -0.0001
  0.1357   0.0000   0.6179   0.1868  -0.0140
  0.0016  -0.0012   0.0000   0.0197   0.0000
 -0.0004   0.0000   0.0000   0.0000   0.0061
SigmaU~*100
  0.0007  -0.0002   0.0363   0.0004  -0.0001
```

```
 -0.0002   0.0052   0.0873   0.0094   0.0000
  0.0363   0.0873  43.5302   0.3895  -0.0133
  0.0004   0.0094   0.3895   0.0391  -0.0001
 -0.0001   0.0000  -0.0133  -0.0001   0.0037
end of ML estimation
```

SVAR FORECAST ERROR VARIANCE DECOMPOSITION OF GDP

Proportions of forecast error in "gdp_log"

accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.01	0.48	0.00	0.51	0.00
2	0.00	0.33	0.00	0.66	0.00
3	0.00	0.26	0.01	0.71	0.02
4	0.01	0.24	0.02	0.69	0.04
5	0.01	0.23	0.03	0.67	0.06
6	0.02	0.23	0.05	0.64	0.07
7	0.03	0.22	0.08	0.60	0.08
8	0.03	0.22	0.10	0.56	0.08
9	0.04	0.22	0.13	0.53	0.08
10	0.05	0.21	0.15	0.51	0.08
11	0.06	0.21	0.17	0.48	0.08
12	0.06	0.21	0.18	0.46	0.08
13	0.07	0.21	0.19	0.45	0.08
14	0.07	0.21	0.20	0.44	0.08
15	0.08	0.21	0.21	0.43	0.08
16	0.08	0.21	0.22	0.42	0.07
17	0.08	0.21	0.22	0.41	0.07
18	0.09	0.21	0.23	0.41	0.07
19	0.09	0.21	0.23	0.40	0.07
20	0.09	0.21	0.23	0.40	0.07

SVAR FORECAST ERROR VARIANCE DECOMPOSITION OF GDP DEFLATOR

Proportions of forecast error in "gdpdef_log"
accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	1.00	0.00	0.00	0.00	0.00
2	0.99	0.00	0.00	0.01	0.00
3	0.98	0.01	0.01	0.01	0.00
4	0.96	0.00	0.01	0.02	0.00
5	0.95	0.00	0.01	0.04	0.00
6	0.93	0.00	0.01	0.05	0.00
7	0.92	0.00	0.01	0.06	0.00
8	0.91	0.00	0.01	0.07	0.00
9	0.90	0.00	0.01	0.09	0.00
10	0.88	0.00	0.01	0.10	0.00
11	0.87	0.00	0.01	0.10	0.01
12	0.87	0.00	0.01	0.11	0.01
13	0.86	0.00	0.01	0.12	0.01
14	0.85	0.00	0.01	0.13	0.02
15	0.84	0.00	0.01	0.13	0.02
16	0.83	0.00	0.01	0.14	0.03
17	0.82	0.00	0.00	0.14	0.03
18	0.81	0.00	0.00	0.15	0.04
19	0.79	0.00	0.00	0.16	0.04
20	0.78	0.00	0.00	0.16	0.05

SVAR FORECAST ERROR VARIANCE DECOMPOSITION OF M2

Proportions of forecast error in "m2_log"
accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.00	0.00	0.00	0.00	1.00
2	0.02	0.00	0.08	0.00	0.89
3	0.02	0.00	0.16	0.00	0.81
4	0.03	0.00	0.21	0.00	0.76
5	0.03	0.00	0.24	0.00	0.73
6	0.02	0.00	0.26	0.00	0.71
7	0.02	0.00	0.27	0.00	0.70

8	0.02	0.00	0.28	0.01	0.70
9	0.02	0.00	0.27	0.01	0.69
10	0.01	0.00	0.27	0.03	0.69
11	0.01	0.00	0.26	0.05	0.68
12	0.01	0.00	0.24	0.08	0.66
13	0.02	0.00	0.23	0.11	0.64
14	0.02	0.00	0.22	0.14	0.62
15	0.03	0.00	0.20	0.17	0.60
16	0.03	0.01	0.19	0.20	0.57
17	0.04	0.01	0.18	0.23	0.54
18	0.05	0.01	0.17	0.26	0.52
19	0.06	0.01	0.16	0.28	0.49
20	0.06	0.01	0.15	0.31	0.47

SVAR FORECAST ERROR VARIANCE DECOMPOSITION OF INTEREST RATE

Proportions of forecast error in "intrate"
accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.04	0.00	0.88	0.08	0.00
2	0.07	0.00	0.78	0.15	0.00
3	0.12	0.01	0.66	0.20	0.00
4	0.16	0.01	0.59	0.23	0.00
5	0.18	0.01	0.55	0.26	0.01
6	0.20	0.01	0.50	0.28	0.01
7	0.23	0.01	0.46	0.29	0.01
8	0.25	0.01	0.43	0.30	0.01
9	0.27	0.01	0.40	0.30	0.02
10	0.29	0.01	0.38	0.31	0.02
11	0.31	0.01	0.36	0.31	0.02
12	0.32	0.01	0.34	0.31	0.02
13	0.33	0.01	0.33	0.31	0.02
14	0.35	0.01	0.32	0.30	0.03
15	0.36	0.01	0.31	0.30	0.03
16	0.36	0.01	0.30	0.30	0.03
17	0.37	0.01	0.29	0.30	0.03

18	0.38	0.01	0.28	0.30	0.03
19	0.38	0.01	0.28	0.30	0.03
20	0.38	0.01	0.27	0.30	0.03

SVAR FORECAST ERROR VARIANCE DECOMPOSITION OF INVESTMENT

Proportions of forecast error in "inv_log"
accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.01	0.00	0.00	0.99	0.00
2	0.01	0.00	0.00	0.98	0.00
3	0.01	0.00	0.02	0.96	0.02
4	0.00	0.01	0.03	0.93	0.03
5	0.00	0.01	0.04	0.91	0.04
6	0.00	0.02	0.05	0.89	0.04
7	0.00	0.02	0.07	0.86	0.04
8	0.00	0.02	0.09	0.84	0.05
9	0.00	0.03	0.11	0.82	0.05
10	0.00	0.03	0.13	0.80	0.04
11	0.00	0.03	0.14	0.79	0.04
12	0.00	0.03	0.15	0.78	0.04
13	0.00	0.03	0.16	0.77	0.04
14	0.00	0.03	0.16	0.76	0.04
15	0.00	0.04	0.17	0.76	0.04
16	0.00	0.04	0.17	0.75	0.04
17	0.00	0.04	0.17	0.75	0.04
18	0.00	0.04	0.17	0.75	0.04
19	0.00	0.04	0.17	0.74	0.04
20	0.00	0.04	0.17	0.74	0.04

A.2.2 Monetarist model

This is a B-model

Step 1:

```
Obtaining starting values from decomposition of correlation matrix...
Iterations needed for correlation matrix decomposition:  96.0000
Vector of rescaled starting values:
  0.0027
 -0.0007
  0.1357
  0.0016
 -0.0004
  0.0062
  0.0175
  0.0032
  0.4994
 -0.0002
 -0.0016
  0.4093
  0.0090
  0.0061

Step 2:
Structural VAR Estimation Results
ML Estimation, Scoring Algorithm (see Amisano & Giannini (1992))
Convergence after 1 iterations
Log Likelihood: 3635.3377
Structural VAR is over-identified with   1.0000  degrees of freedom
LR Test: Chi^2(  1.0000 ):   6.7679 , Prob:   0.0093

Estimated A matrix:
  1.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   1.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   1.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   1.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   1.0000

Estimated standard errors for A matrix:
  0.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   0.0000
```

```
  0.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   0.0000

Estimated B matrix:
  0.0027   0.0000   0.0000   0.0000   0.0000
 -0.0007   0.0062   0.0032  -0.0016   0.0000
  0.1357   0.0000   0.4994   0.4093   0.0000
  0.0016   0.0175   0.0000   0.0090   0.0000
 -0.0004   0.0000  -0.0002   0.0000   0.0061

Estimated standard errors for B matrix
  0.0001   0.0000   0.0000   0.0000   0.0000
  0.0005   0.0059   0.0107   0.0017   0.0000
  0.0462   0.0000   0.9221   1.1247   0.0000
  0.0014   0.0127   0.0000   0.0248   0.0000
  0.0004   0.0000   0.0004   0.0000   0.0003

A^-1*B
  0.0027   0.0000   0.0000   0.0000   0.0000
 -0.0007   0.0062   0.0032  -0.0016   0.0000
  0.1357   0.0000   0.4994   0.4093   0.0000
  0.0016   0.0175   0.0000   0.0090   0.0000
 -0.0004   0.0000  -0.0002   0.0000   0.0061
SigmaU~*100
  0.0007  -0.0002   0.0363   0.0004  -0.0001
 -0.0002   0.0052   0.0873   0.0094   0.0000
  0.0363   0.0873  43.5302   0.3895  -0.0133
  0.0004   0.0094   0.3895   0.0391  -0.0001
 -0.0001   0.0000  -0.0133  -0.0001   0.0037
end of ML estimation


SVAR FORECAST ERROR VARIANCE DECOMPOSITION OF GDP

Proportions of forecast error in "gdp_log"
                     accounted for by:
forecast horizon  gdpdef_log   gdp_log   intrate    inv_log    m2_log
```

1	0.01	0.75	0.20	0.05	0.00
2	0.00	0.82	0.16	0.02	0.00
3	0.00	0.87	0.10	0.01	0.02
4	0.01	0.87	0.07	0.01	0.04
5	0.01	0.86	0.06	0.01	0.06
6	0.02	0.84	0.05	0.02	0.07
7	0.03	0.82	0.04	0.04	0.08
8	0.03	0.80	0.04	0.05	0.08
9	0.04	0.78	0.04	0.06	0.08
10	0.05	0.76	0.04	0.07	0.08
11	0.06	0.74	0.04	0.08	0.08
12	0.06	0.72	0.04	0.09	0.08
13	0.07	0.71	0.04	0.10	0.08
14	0.07	0.70	0.04	0.11	0.08
15	0.08	0.70	0.04	0.11	0.08
16	0.08	0.69	0.04	0.12	0.07
17	0.08	0.69	0.04	0.12	0.07
18	0.09	0.68	0.04	0.12	0.07
19	0.09	0.68	0.04	0.13	0.07
20	0.09	0.68	0.04	0.13	0.07

SVAR FORECAST ERROR VARIANCE DECOMPOSITION OF GDP DEFLATOR

Proportions of forecast error in "gdpdef_log"
accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	1.00	0.00	0.00	0.00	0.00
2	0.99	0.00	0.00	0.01	0.00
3	0.98	0.00	0.00	0.02	0.00
4	0.96	0.01	0.00	0.02	0.00
5	0.95	0.02	0.00	0.03	0.00
6	0.93	0.02	0.00	0.04	0.00
7	0.92	0.03	0.00	0.04	0.00
8	0.91	0.04	0.00	0.05	0.00
9	0.90	0.05	0.00	0.05	0.00
10	0.88	0.06	0.00	0.05	0.00

11	0.87	0.06	0.00	0.05	0.01
12	0.87	0.07	0.00	0.05	0.01
13	0.86	0.08	0.00	0.05	0.01
14	0.85	0.08	0.00	0.05	0.02
15	0.84	0.09	0.00	0.05	0.02
16	0.83	0.09	0.00	0.05	0.03
17	0.82	0.10	0.00	0.05	0.03
18	0.81	0.11	0.00	0.05	0.04
19	0.79	0.11	0.00	0.05	0.04
20	0.78	0.12	0.00	0.05	0.05

SVAR FORECAST ERROR VARIANCE DECOMPOSITION OF M2

Proportions of forecast error in "m2_log"
accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.00	0.00	0.00	0.00	1.00
2	0.02	0.00	0.07	0.02	0.88
3	0.02	0.00	0.12	0.06	0.80
4	0.03	0.01	0.14	0.08	0.75
5	0.03	0.01	0.16	0.09	0.71
6	0.02	0.01	0.18	0.09	0.69
7	0.02	0.02	0.18	0.09	0.68
8	0.02	0.03	0.18	0.09	0.68
9	0.02	0.05	0.18	0.08	0.68
10	0.01	0.07	0.17	0.07	0.67
11	0.01	0.10	0.16	0.07	0.66
12	0.01	0.13	0.15	0.06	0.65
13	0.02	0.17	0.14	0.05	0.63
14	0.02	0.20	0.13	0.05	0.61
15	0.03	0.24	0.12	0.04	0.58
16	0.03	0.27	0.11	0.04	0.56
17	0.04	0.30	0.10	0.03	0.53
18	0.05	0.33	0.09	0.03	0.51
19	0.06	0.35	0.08	0.03	0.48
20	0.06	0.37	0.08	0.02	0.46

SVAR FORECAST ERROR VARIANCE DECOMPOSITION OF INTEREST RATE

Proportions of forecast error in "intrate"
accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.04	0.00	0.57	0.38	0.00
2	0.07	0.02	0.55	0.37	0.00
3	0.12	0.06	0.50	0.31	0.00
4	0.16	0.08	0.46	0.30	0.00
5	0.18	0.10	0.42	0.30	0.01
6	0.20	0.12	0.39	0.28	0.01
7	0.23	0.13	0.36	0.27	0.01
8	0.25	0.14	0.33	0.26	0.02
9	0.27	0.14	0.31	0.25	0.02
10	0.29	0.15	0.29	0.24	0.02
11	0.31	0.15	0.28	0.24	0.02
12	0.32	0.15	0.27	0.23	0.02
13	0.33	0.16	0.26	0.23	0.03
14	0.35	0.16	0.25	0.22	0.03
15	0.36	0.16	0.24	0.22	0.03
16	0.36	0.16	0.23	0.22	0.03
17	0.37	0.16	0.23	0.21	0.03
18	0.38	0.16	0.22	0.21	0.03
19	0.38	0.16	0.22	0.21	0.03
20	0.38	0.16	0.21	0.20	0.03

SVAR FORECAST ERROR VARIANCE DECOMPOSITION OF INVESTMENT

Proportions of forecast error in "inv_log"
accounted for by:

forecast horizon	gdpdef_log	gdp_log	intrate	inv_log	m2_log
1	0.01	0.79	0.00	0.21	0.00
2	0.01	0.84	0.00	0.14	0.00
3	0.01	0.87	0.00	0.11	0.02

4	0.00	0.88	0.00	0.08	0.03
5	0.00	0.89	0.00	0.06	0.03
6	0.00	0.90	0.01	0.05	0.04
7	0.00	0.90	0.01	0.04	0.04
8	0.00	0.90	0.02	0.04	0.04
9	0.00	0.89	0.02	0.04	0.04
10	0.00	0.89	0.03	0.04	0.04
11	0.00	0.89	0.03	0.04	0.04
12	0.00	0.89	0.03	0.04	0.04
13	0.00	0.89	0.04	0.04	0.04
14	0.00	0.89	0.04	0.04	0.04
15	0.00	0.89	0.04	0.04	0.04
16	0.00	0.89	0.04	0.04	0.04
17	0.00	0.89	0.04	0.04	0.04
18	0.00	0.89	0.04	0.04	0.04
19	0.00	0.88	0.04	0.04	0.04
20	0.00	0.88	0.04	0.04	0.04