Dissertation
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PhD thesis CERGE-EI

Report on CERGE-EI PhD thesis "Essays on Aggregate Performance and Competition" by Vahagn Jerbashian

I enjoyed reading this thesis and my overall assessment is that Vahagn Jerbashian should be awarded a PhD. All three papers included in the thesis show originality and are publishable in respectable journals, or in top journals after some revisions. The thesis demonstrates that Vahagn Jerbashian has strong skills in theoretical modelling as well as empirical work. In what follows, I will give somewhat more detailed comments on each chapter below. It should be noted that I will aim to be as critical as I would be if I were to review these papers for a top journal and my comments should be therefore seen as suggestions before the ultimate submission to journals rather than a requirement for the thesis itself, for which I do not explicitly ask for changes. I would be happy to discuss Vahagn's responses to my comments.

Chapter 1: "Knowledge Licensing in a Model of R&D-driven Endogenous Growth"

Chapter 1 endogenizes selling and buying knowledge in a modified version of an endogenous growth model. The main innovation is to explicitly model licensing - that is instead of assuming that there are costless spillovers that individual firms do not internalize (as in most of the endogenous growth literature), there is a market for knowledge where firms have access to innovations by other firms if they pay a price and can sell their knowledge about their own innovations. The main finding is that in most settings analyzed, licensing leads to higher growth than the benchmark settings - the standard costless spillovers and another extreme case of no spillovers.

I like the idea, as superficial intuition would suggest that paying for existing knowledge rather than accessing it for free would reduce innovation and growth, which is opposite to the prediction of the model. At the same time the main finding is intuitive. Namely, it is well known that in the standard endogenous growth models there is underinvestment in innovation in decentralized equilibrium compared to the social planner problem. One of the main reasons for this is that individual firms do not obtain the full benefits of their innovation because they do not profit from making it easier for other firms to innovate. If there is costly licensing, then an individual firm does not just lose profits by paying to other firms for existing knowledge, but also obtains rents from other firms for its own innovations (equation 1.18). Therefore, despite the fact that there are costs related to accessing other firms' innovation in the environment with licensing, the benefits of selling ones own knowledge outweigh this cost. This positive effect is also robust to endogenizing the number of high-tech firms even though licensing reduces the equilibrium number of high-tech/innovative firms.

This chapter also makes a link between product market competition and innovation/growth and argues that more competition tends to be beneficial for growth in most settings (e.g., see Figure 1.1 that reports a positive relation between productivity growth and number of firms for costless-spillovers model and licensing model, while it is hump-shaped for the no-spillovers case). There is also an argument showing that more tight Bertrand-like competition in the product market vs. Cournot-like competition in the product market leads to higher growth. While sensible within the particular model, the argument may be somewhat oversold. Namely, the model focuses on differentiated goods that are somewhat substitutable, but not perfect substitutes. Producers of each variety still have monopolistic power and will not be overtaken by another firm producing a better quality product as in quality ladder models. In that sense, I would still tend to believe that more generally, the relationship between innovation and product market competition in inverted U-shaped as predicted by the literature in that spirit. I am also somewhat puzzled about how to understand the references to "Bertrand" and "Cournot" in this context as these are mostly understood in the case of limited number of producers of a homogeneous good, and not differentiated goods. Therefore, I find it somewhat non-standard.

- *In this model the positive relationship between different types of competitive pressure and innovation holds as long as the high-tech firms have sufficient incentives to innovate. I have clarified this in introduction and results sections. In particular, I have replaced*
  - *the 1st sentence of the 2nd paragraph on page* 3 *with:*
    "I show that when there is an exchange of knowledge among high-tech firms in the form of licensing or spillovers, innovation in the high-tech industry and economic growth increase with the number of high-tech firms as long as these firms have sufficient incentives to innovate."
  - *the 1st and 2nd sentences of the 3rd paragraph on page* 4 *with:*
    "I further show that in all the setups that I consider innovation in the high-tech industry and economic growth increase with the intensity of competition, again, provided that high-tech firms have sufficient incentives to innovate. Under such condition, tougher competition, which is defined as the type of competition with lower mark-ups (Bertrand vs. Cournot; Sutton, 1991), also implies more innovation in the high-tech industry and higher growth."
- *In results section on page* 28 *I have added a discussion about the relation of the results with empirical findings:*
  "In this respect, if there are no subsidies that keep the profits of high-tech firms non-negative, the positive relationship between innovation and ε holds as long as high-tech firms have sufficient profits to cover the costs of R&D. Profits of high-tech firms and ε are inversely related. Once profits net of R&D expenditures are equal to zero increasing ε reduces innovation to zero. Therefore, if there are no subsidies the relationship between intensity of product market competition (ε) and innovation has an "inverted-U" shape. Such a relation is consistent with Schumpeter's argument that firms need to be sufficiently big in order to innovate.

Moreover, it is in line with the empirical findings of Aghion et al. (2005) and provides an alternative explanation for those findings."

- *I have replaced footnote* 5 *with:*
  "The results regarding the relation between innovation and different types of competitive pressure are consistent with the empirical findings of Nickell (1996), Blundell et al. (1999), and Aghion et al. (2005)."

- *Indeed, this paper uses generalizations of standard Bertrand and Cournot types of competition. These generalizations allow considering differentiated goods and are often used in the literature (e.g., van de Klundert and Smulders, 1997). In the model section I have added footnote* 15 *in order to clarify that:*
  "Cournot and Bertrand types of competition are modeled as in van de Klundert and Smulders (1997)."

Given all this, my more concrete suggestions for improving that paper are the following:

*I do not see the benefit of analyzing "Cournot" vs. "Bertrand" and would suggest to stick to only what is referred as "Cournot". I believe that having two cases distorts the main message and does not seem to produce many additional interesting and general qualitative insights.

* The paper makes a lot of effort on explaining comparative statics with respect to exogenous parameters, but I believe that the message would be stronger if relatively more effort would be spent on explaining the intuition of the main finding - why is licensing better than costless spillovers.

In the current draft of the paper I have reduced the text related to comparative statics with respect to exogenous parameters. For example, I have dropped Table 1.1 and Table 1.2 on page 34 of the previous draft of the text. In the journal version of the paper it can be valuable to spend more effort in this direction and to consider dropping one of the types of competition.

* In the subsection of 1.2, "Final Goods", while mathematically equivalent, I would have preferred defining the main problem as
$\max_{\{x_i,L_y\}} Y - wL_y - \sum_{i=1}^{N} p_{x_i}x_i$, s.t. $Y = \tilde{X} \cdot X^{\sigma} L_y^{1-\sigma}$ where X is defined by (1.5). and later defining the same price index P_X from this problem. Alternatively, if the current setup is preferred, it would seem more transparent to introduce two perfectly competitive sectors - one producing a final good from composite X and labor; and another perfectly competitive sector producing the composite good X from x_i-s.

I have reshaped this part. It now reads:

"The representative producer solves the following problem.

$$\max_{L_Y, X} \left\{ Y - wL_Y - \sum_{i=1}^{N} p_{x_i} x_i \right\}$$
$$s.t.$$
$$(1.4),$$

where Y is the numeraire. The optimal rules that follow from this problem describe the final goods producer's demand for labor and for high-tech goods.

$$[L_Y] : wL_Y = (1-\sigma)\, Y,$$
$$[x_j] : x_j = X \left(\frac{P_X}{p_{x_j}} \right)^{\varepsilon} \text{ for } \forall j = 1, ..., N,$$

where P_X is an index of p_x

$$P_X = \left(\sum_{i=1}^{N} p_{x_i}^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}.$$

By construction this index is the private marginal value of X. Moreover, given that X is constant returns to scale in high-tech goods the following two conditions hold.

$$P_X X = \sigma Y,$$
$$P_X X = \sum_{i=1}^{N} p_{x_i} x_i."$$

* When talking about the knowledge licensing in (1.12) on page 9, the paper could be shortened by introducing the benchmarks of knowledge spillovers (1.13 and 1.14) and no exchange of knowledge (1.15 and 1.16) through parameter restrictions on $u_{i,j}$.

* Figure 1.1 on page 26 is somewhat unreadable without following the text as red/blue lines under assumptions S1-S3 (in particular S1,S2) look almost the same, so it could be formatted better.

* Overall I believe that the paper could by shortened as it is somewhat too long. The paper appears to be somewhat too focused on minor details, comparative statics and extensions. I believe that the paper would benet from shortening and dropping some on these parts and instead would make more effort in making the intuition of the main finding clearer. Some of the mathematical details in the main body (especially in the second part) could be moved to the Appendix.

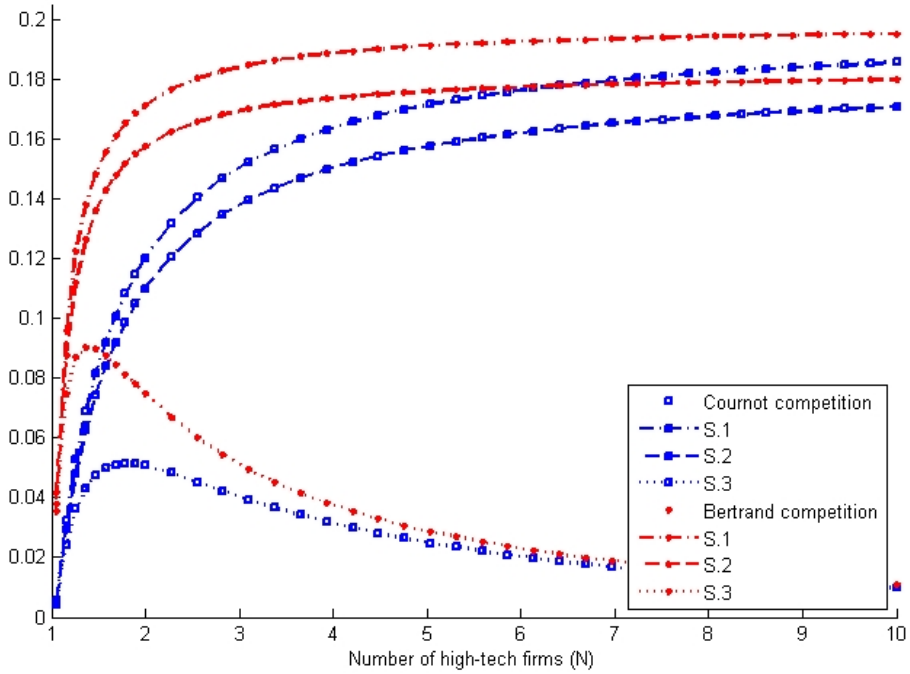
* As mentioned before, the arguments on the relationship between innovation and competition appear somewhat less convincing, while quite prominent in the introduction. I would suggest to reduce emphasis on that. Also, the arguments about competition are not very clearly written at times.

- *I have rewritten the explanation for S.3 case in the following manner:*
  "It is clear that (1.12) and (1.13) reduce to (1.15) in case when there is no exchange of knowledge among high-tech firms [i.e., (1.12) and (1.15) are equivalent if $u_{i,j} = 0$ for $\forall i \neq j$ and limiting case $\alpha = 0$; (1.13) and (1.15) are equivalent

if $u_{i,j} = 0$ for $\forall i \neq j$.] Therefore, the comparison between results for knowledge accumulation processes (1.12), (1.13), and (1.15) can highlight the effect of knowledge exchange among high-tech firms. Further, the knowledge accumulation process (1.15) might be interpreted as if the exchange of knowledge among high-tech firms is banned (e.g., because of antitrust concerns) or it is made very costly."

- *I have reshaped the figure and added an explanatory note:*

Figure 1: *The Growth Rate of Productivity in S.1-3 Cases*



Note: This figure plots g_λ as a function of N for parameter values $\theta = 4$, $\rho = 0.01$, $\sigma = 0.3$, $\mu = 0.01$, $\varepsilon = 4$, $L = 1$, $\xi = 1$, and $\alpha = 0.1$ and for Cournot and Bertrand types of competition.

- *In order to reduce emphasis on the effect of different measures of competitive pressure in introduction I have placed the following paragraph at the beginning of the discussion of results: "I show that high-tech firms innovate more and the economy grows at a higher rate in case when there is knowledge licensing among high-tech firms compared to the case when there are knowledge spillovers. This result holds since in case when there is knowledge licensing high-tech firms better appropriate the benefits from their R&D. The availability of complementary knowledge also motivates innovation in the high-tech industry. High-tech firms innovate more and the economy grows at a higher rate in case when there is an exchange of knowledge among high-tech firms than when there is no exchange. This is because R&D builds on a bigger pool of knowledge in case when there is an exchange of knowledge. Moreover, in case when there is no knowledge exchange high-tech firms might not innovate at all if there are many of them in the market. The driver behind this result is the scarcity of R&D inputs available per high-tech firm if there are many such firms."*

Chapter 2: "The Impact of Telecommunication Technologies on Com- petition in Services and Goods Market: Empirical Evidence" (with Anna Kouchanova)

This paper asks whether adoption of telecommunication technologies increases the level of product market competition of goods and services. The paper looks at countries in the European Union and tests whether wider adoption of these technologies at a country level has a disproportionately larger effect on competition in industries that depend on these technologies more (the measure of industry dependence is based on the US data and on Japans data as a robustness check). The paper finds strong effects. Overall I find the empirical work competently executed and convincing, the paper is careful in discussing the method, alternative interpretations and performs a number of robustness checks. Interestingly, there do not appear to be significantly different effects for services compared to goods sector.

As the paper argues, the main reasons why one would expect a positive relationship between competition and telecommunication technologies (and in particular Internet) is that such technologies reduce information acquisition costs, can lower entry costs for many industries and make it easier for consumers to compare prices. Also, most of the theoretical and empirical literature cited in this chapter also point towards a positive relationship. Therefore, one would have expected the paper to focus on establishing whether the effect is strong enough rather than question the sign of the effect. Yet the paper appears to prefer to motivate itself by taking the stance that the sign of the relationship is uncertain - as the second paragraph states "diffusion of telecommunication technologies can help firms to loosen competition". The arguments for the opposite case are currently either non-convincing or very brief. Given this, my recommendation is that a revised version of the paper would benet either from making more efforts in explaining why the relationship is so far uncertain or motivating better why the question about the size of the effect is interesting. Currently, the paper may be exposed to criticism that the main effect is not very surprising. While testing a sensible relationship is always a valid exercise, polishing the motivation could improve the chances of this paper being well published and cited.

I have changed the name of this chapter. It currently reads as "How Telecommunication Technologies Affect Product Market Competition: Empirical Evidence".

I have added more elaborate discussion why there can be positive relationship between the diffusion of telecommunication technologies and competition.

- *In introduction I have reshaped paragraph* 3. *It now reads:*
  "These arguments are certainly not conclusive, however. It may be argued as well that the diffusion of telecommunication technologies can help firms loosen competition. For example, firms can use the internet and other types of telecommunication networks for (extensive) advertisement of their products, which can help to increase product differentiation. In turn, lower information acquisition costs can help firms to learn about the demand and the general market environment. This can allow them to better target their marketing appeals and can increase price discrimination and product differentiation (for well-known examples see Taylor, 2004, Mikians et al., 2012)."

- *In the section for theoretical background I have rewritten paragraph* 4 *on page* 83*. It now reads:*
  "These arguments indicate that there can be a positive link between the diffusion of telecommunication technologies and the (potential) entry of firms. Therefore, they indicate that the diffusion can intensify the competition in services and goods markets which is in line with the conjectures of, for example, Freund and Weinhold (2004) and Czernich et al. (2011).However, these arguments are certainly not conclusive. In this regard, it can be argued as well that the diffusion of telecommunication technologies can help firms gain market power. For example, it may help firms to increase product differentiation through the (extensive) advertisement of products over the internet and other types of telecommunication networks. Moreover, lower information acquisition costs can help firms to learn about the demand and the general market environment. Therefore, they can help to increase price discrimination and product differentiation. Such practices seem to be commonly applied in online as well as traditional firms (Taylor, 2004). Online firms, for example, can track via visited web sites, search keywords, and IP address the preferences and location of visitors and use that information for targeting their marketing appeals."

- *I have also added footnote* 4 *on page* 83*:*
  "Freund and Weinhold (2004) hypothesize that the diffusion of telecommunication technologies and, in particular, of internet can reduce the costs of entry. Further, they offer a stylized model where the reduction of entry costs induces entry of firms and increases the intensity of competition."

My other more minor comments are the following

* While most of the motivation mentions the benefits of Internet, the measure of telecommunication technologies (page 82) relies only on the number of fixed lines and mobile subscribers per capita. So I wonder why the paper does not attempt to use somewhat more directly Internet related measures instead (or in addition)? Especially fixed lines could make the measure rather imprecise, because countries differ in the degrees at which Internet connection comes though a fixed line rather than cable; people may be substituting fixed lines for mobile phones at different degrees in different countries. It would seem that country level data on Internet connections should not be hard to obtain, even though it may be highly correlated with the current measure. (there is an alternative measure in Appendix, telecoms revenue, but it potentially suffers from the same and additional problems discussed). Alternatively, if the goal is to avoid using Internet data and argue that there is already strong effects due to different phones, it would seem to require somewhat different motivation.

The introductory section offers a motivating example which argues that the diffusion/uptake of internet can increase competition. This example was selected since it is succinct. The argument, however, applies for broader set of information and communication technologies: telecommunication technologies. This is one of the reasons why this paper uses the number of fixed-line and mobile telephone subscribers per capita. Such a measure can also reflect the diffusion of internet in a country since, for example, fixed-lines are used extensively for dial-up and DSL internet.

Indeed, countries can differ in terms of the use of fixed telephone lines (and mobile phones) for internet. As long as internet is the driver behind our results and industry level competitive pressures do not affect the use of fixed telephone lines (and mobile phones) for internet this can create attenuation bias in our results. Paragraph 1 *of the section that discusses this measure (page* 86*) acknowledges that potentially it is noisy.*

For robustness checks, however, we have used measures that are more directly related to the diffusion of internet. In particular we have used the per capita number of internet subscribers (footnote 6*) and the per capita number of broadband subscribers. The results are basically the same as for the main measure (I have added in Table 2.12 the results for internet subscribers).*

*The paper includes a Technical Appendix which presents a model and some additional empirical tests. Even if the Technical Appendix would not be included when the paper is submitted to journals, it would be still good to have a Section briefly discussing the additional findings. Within the thesis, it is unclear why the model is included if it is not referred in the text.

In methodology section I have included footnote 4 *in the text in (page* 84*):*
"(In the Technical Appendix we offer a very stylized and simplistic model that delivers predictions in line with our inference.)"

* The paper would be nicer to read if some of the crucial Tables (e.g., Table 2.2 and other main results) would be in the main text rather than in the Appendix. It would also be better if Table A with definitions should be before the Summary Statistics Table 2.1

* One of the robustness checks considers measures of country level institutional variables (starting from page 91). While the general institutional environment would be already captured by the country dummies, the paper tests additional interaction terms. I am not sure that this part is necessary, but if it is included, it could be better explained.

* The "cheat-chat" on page 82 should be "chit-chat", and would be better replaced with another expression.

- *The main motivation behind testing the effect of institutional variables is that these are argued to matter for firm entry which can affect competitive pressure. (Indeed, however, it can be valuable to shorten this section in the journal version of this paper.)*
- *I have replaced "An example would be chit-chat over the phone" with "An example would be an uninformative discussion over the phone about weather".*

Chapter 3: "Specific and General Human Capital in an Endogenous Growth Model" (with Evangelia Vourvachaki and Sergey Slobodyan)

I find this chapter to be on one with the highest potential, but perhaps the least polished at this stage. Before submitting to journals, this paper would benefit from more work and potential rethinking. My main concern is the fact that there seems to be little connection between the empirical motivation and the theory part, and I find it hard to see a convincing connection between the two. As a model the theory part is very nice, but I would personally interpret and motivate it differently. The empirical idea that is somewhat more brief could also potentially evolve to another interesting paper with a different model. Both of these papers could be separately very interesting.

Let me first propose an alternative interpretation of the main model. Instead of calling H_g and H_s "general" and "specific" human capital, a more direct fit to think of the variable labelled as H_g to be human capital (or time) used for doing/performing (perhaps more routine or non-creative) tasks. The variable H_s could be interpreted as human capital (or time) used for thinking and learning about different tasks as well as about innovation. Within this interpretation, it seems sensible that production of any output would require both types of human capital (even by the same person), which justifies (3.1). It also seems sensible that spending time on thinking can improve skills in performing routine tasks, as in equation (3.7). Thinking and learning can also be used to improve more broad understanding about the production process and come up with innovative ideas as in equation (3.6) and (3.9). Because the time and capacity to learn and think are limited, agents need to choose allocation of their thinking effort. Given this interpretation, the model shows that due to externalities present in innovation, there is a tendency in decentralized equilibrium to spend relatively too much time on improving skills in performing less creative tasks rather than on more creative tasks and innovation. The paper also shows that appropriate taxing of wage income and giving subsidies to workers would increase the growth rate to equal the social planners. Such policy could perhaps be implemented by subsidizing firms who pay for workers to take time off to learn about more broad ideas (page 130). It should also be noted that the model effectively implies somewhat sophisticated wage contract (that pays separately for routine and thinking tasks directly related to production, see (3.12)). However, fortunately it turns out that the optimal tax rate is the same for both type of tasks and does not rely on sophistication of the wage contract, which still allows to link it with policy suggestion. Provided such interpretation, the paper would need a different motivation. Also, interpreted like that, it would also somewhat relate to a working paper by Legros, Newman and Proto "Smithsonian Growth Through Creative Destruction" that also discusses different kind of effort and innovation, while delivering different insights. If the goal would still be to use some empirical data to motivate, then that part would require more work that matches this interpretation.

If one were to focus on specific and general human capital, it is also worth noting that readers may be expecting to see a trade-off within a profession. E.g., an engineer working for an automotive industry could have and choose to accumulate skills about engineering in general or specific knowledge about automotive industry. Also, a manager could be more focused on a specific firm (or industry) or accumulate more general managerial skills (see e.g., Giannetti 2011, Journal of Financial Intermediation, in the

context of managerial compensation). In such case, it is unclear whether innovation is better thought to be created by specific of general human capital. In contrast to this, the empirical motivation appears to have classified everyone within the same profession as either specific or general. While such approach could also be interesting and justified, I find the classification on Table 3.7 in Appendix counterintuitive in the context of the models assumption that it is specific human capital rather than general human capital that contributes to innovation. As an example, Table 3.7 classifies models, salespersons and demonstrators as having specific human capital, while mathematical, engineering science professionals as general human capital. Wouldn't one expect the second group to be more likely to contribute to innovation? Looking at Table 3.7, there are many more cases where what is classified as general human capital is more likely to contribute to innovation.

Regarding the existing empirical data, it could definitely be interesting to understand which type of professions are useful for many industries as opposed to a few. However, if that is the goal of the paper, I would have expected a very different model and a clear explanation how different skills/professions contribute to innovation and growth. I would imagine that a more appropriate theoretical model for that question should include more than one industry (as opposed to the current model with one final good), different groups of workers who can only work in one sector or several and some good story about which type of skills generate innovation. Also that paper could be itself a very interesting and probably a separate paper.

The model presented in this chapter is indeed quite general and, therefore, it can permit alternative interpretations. It is an attempt to offer possible explanations behind the gradual decline in the share of specific human capital as observed in the Czech Republic and show its possible welfare consequences in a parsimonious setup. Indeed, a more elaborate version of the model with more than one production sector can be valuable in order to further this task and take into account the possible trade-offs between developing general human capital versus specific human capital.

In the current model R&D is performed in "academia" where according to our data (Table 3.8 *and Table* 3.9*) the majority of labor force have specific human capital. However, if R&D was performed in industrial sector some types of general human capital indeed would be more likely to contribute to innovation. Although it seems that the first type of R&D process might not be inappropriate for the Czech Republic at least in the 90s it is ultimately empirical question which type of human capital contributes more to innovation. Therefore, indeed more data work can be valuable.*

Final comment

As mentioned at the beginning, the thesis is overall interesting and shows good skills. As a general comment, it seems that all chapters would benefit (at different degrees) from more work on writing a good introduction and polishing the motivation before submitting to journals. I hope that my comments are helpful in revising the papers. While I do not insist on changes, a small change that would benefit the thesis itself would be to improve the Abstract on (i) and (ii) as it currently provides too little information and is at times confusing, e.g., it does not define what is "licensing" in Chapter 1, it also gives a potentially misleading impression about Chapter 3.

I have rewritten the abstract. It now reads:
"This thesis examines various forces that affect aggregate performance. In particular, it focuses on competitive pressures and analyses their determinants. It also analyses the importance of human capital portfolio composition for aggregate performance. Specifically, in the first chapter it offers an endogenous growth framework where it models knowledge (patent) licensing among high-tech firms. In such a framework it evaluates how different types of competitive pressure can matter for innovation in high-tech industries. In the second chapter it offers empirical evidence that the country-wide uptake of telecommunication technologies increases competition in services and goods markets. In turn, in the third chapter it defines two types of human capital and suggests how human capital portfolio matters for long-run growth and welfare.

In the first chapter, I present an endogenous growth model where the engine of growth is in-house R&D performed by high-tech firms. I model knowledge (patent) licensing among high-tech firms where licenses are essentially permits for licensees to use the knowledge of licensor in R&D process. I show that if there is knowledge licensing, high-tech firms innovate more and economic growth is higher than in cases when there are knowledge spillovers or there is no exchange of knowledge among high-tech firms. Conditionally that high-tech firms innovate, I show that increasing intensity and toughness of competition in the high-tech industry increases innovation. In case when there is an exchange of knowledge among high-tech firms, in terms of licensing or spillovers, increasing the number of high-tech firms also increases innovation. However, in case when there is no exchange of knowledge the relationship between innovation in the high-tech industry and the number of high-tech firms has an inverted-U shape.

Finally, endogenizing the number of high-tech firms I show again that, in case when there is knowledge licensing, high-tech firms innovate more and economic growth is higher than in the remaining two cases. However, the number of high-tech firms is lower.

In the second chapter, coauthored with Anna Kochanova, we use evidence from 21 EU countries to investigate the relationship between country-wide uptake of high-tech goods such as telecommunications and the level of product market competition in services and goods markets. We find that the uptake of telecommunication technologies significantly increases the level of product market competition. Our result is consistent with the view that the use of these technologies can lower the costs of firm entry. This result contributes to the ongoing debate about the impact of telecommunication technologies, as well as of information and communication technologies, on aggregate performance. In particular, since competitive pressures matter for allocative and productive efficiency, our results imply that the benefits from a particular type of ICT, telecommunication technologies, may come not only from the direct use (e.g., email vs. mail) but also from higher competition.

In the third chapter, coauthored with Evangelia Vourvachaki and Sergey Slobodyan, we propose a new way to horizontally differentiate across skill types, in order to analyze the impact of human capital composition on aggregate economic performance. As in the existing literature, we exploit the cross-occupational differences with an exception that our definition derives from cross-industry heterogeneity in the production function: We differentiate human capital skills according to their "industry specificity." In particular, we define two types of human capital: "specific" and "general." As specific

human capital we define a set of skills that are required for production in few industries. Meanwhile, as general human capital we define a set of skills that are required for production in a broad set of industries.

We use Czech labor survey data to summarize the facts regarding the employment and education level of the two types of human capital for the Czech economy. We find a rather uniform level of skills across the specific and general types of human capital, that agrees with our horizontal differentiation of skills. Moreover, we find that in 2007 approximately 36 percent of total labor input comprises of specific human capital. Our evidence also suggests that this share has been steadily falling since the mid-90s.

To provide an explanation for this trend and illustrate how it can matter for long-run growth and welfare, we build up an endogenous growth model where education and R&D are costly activities. In the model, both general and specific human capital are used in final goods production, while only the specific human capital can serve as input into the educational sector and R&D. We also explicitly take into account the complementarity between basic R&D and education process and positive externalities in R&D. In this respect, the model implies a positive relation between specific human capital intensity and economic growth. This suggests that there can be long-run welfare costs involved in the falling share of specific human capital, as observed in the Czech data. We also discuss optimal educational policies in the presence of market distortions."

Sincerely,

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