Heterogeneous consumption in OLG model with horizontal innovations

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Extended abstract

In this paper we present and investigate a general equilibrium model comprised of the following components: firms producing consumption goods, R&D firms developing new goods, bank sector, and age-structured consumers. A main new feature of the model is, that the goods are heterogeneous and the consumers' preference may depend on the vintage of a particular good, as well as on the current technological frontier. This, together with the involvement of the bank sector, allows to reveal interesting new results about the economic growth.

In the proposed model, agents consume a continuum of perishable goods produced by monopolistically competitive firms. Each firm possesses a permanent patent which the firm buys on perfectly competitive R&D market. The needed investments are provided by a competitive bank sector, and are secured by agents' savings and future firms profits. We consider any improvement in the quality of a good as the invention of a new good by some R&D firm that increases the variety of goods, thus implying only *horizontal innovations*. The variety of goods increases with a speed proportional to the labor employed by perfectly competitive R&D firms with allowance for knowledge spilover, like in Romer (1990).

The consumers, that is, the population in the considered closed economy, have a finite (but uncertain) life span and no bequest intention. This component of the model adapts the Cass and Yaari (1967) framework and differs from the perpetual youth models (e.g., Blanchard, 1985), since we allow for general (possibly realistic) demographic and labor participation/efficiency parameters. A general equilibrium model with realistic survival probability is considered in Boucekkine, de la Croix, and Licandro (2002).

We consider differentiated goods as final *consumption goods*, like in Judd (1985), and disentangle the concepts of productivity growth and growth of the variety of goods. In other words, scientists increase the variety of products rather than the productivity of labor. Indeed, the invention of a new car design does not mean that the sells of cars would increase in total or that new car is produced with less labor. The result of the invention can be that people would just buy cars of new design instead of old one. Although old fashioned cars may still be attractive to some customers and expensive, the production of such cars would decrease. Hence, the total production may stay the same, while the utility of a consumer increases because of the increasing variety of designs, since the consumer can find the most suitable car for her among newly invented designs. We do not specify how productivity of labor (and therefore per capita consumption) depends on R&D activity. This contrasts idea-based growth models (e.g., Romer, 1990) where the invention of a new good (technology) immediately increases productivity of labor and hence per capita consumption. That results in the scale effect prediction when the long run growth rate depends on the population of the country (scale of the economy), which is strongly at odds with 20th-century empirical evidence, see (Jones, 1995a, 1995b). We can still have a scale effect for the growth rate of agents' utilities, because the instantaneous utility depends on the increasing variety of goods. But, per capita consumption may not depend on the variety of goods in our model. Thus, we avoid determining the real growth rate of per capita consumption, included in GDP per capita, and its scale effect predictions.

We study the growth of lifetime discounted utility of generations. All agents are born with zero assets and should be insured from dying indebted. Agents can borrow money from other coexisting generations like in d'Albis, H. and Augeraud-Véron, E. (2011) which is a continuous time generalization of discrete pure exchange OLG models (e.g., Samuelson, 1958; Gale, 1973). In our model we introduce production without physical capital as in Sorger (2011), so that agents can invest only in patents. But, in contrast to Sorger (2011), the agents are not the only investors in the model. The reason for that is the absence of infinitely living agents' cohorts (Blanchard, 1985) or households (Romer, 1990; Sorger, 2011) to own infinitely living firms. The wish of agents to consume all their bounded lifetime income would hamper their investments in firms and stop the growth. Aggregated assets of agents are proved to be bounded and could be even negative like in pure exchange OLG models (Samuelson, 1958; Gale, 1973) depending on the income pattern over the life of an agent. So in the case of endogenous growth there could be imbalance between aggregated assets and the total value of all patents in the economy. To resolve this issue we introduce competitive banking sector which plays a role of infinitely living institution investing in new firms. Banks give loans to the startup firms for purchasing the patents under the pledge of these very patents. Because of the difference between savings and patents' value the economy needs money (liquidity) provided by the banks. Thus, the banks create additional liquidity equal to the change of the value of the patents in the economy. Hence, there are two asset markets in the economy. The one is the market of firms' loans balanced with the values of their patents. The other is the market of agents' savings balanced with their life insurances, according to which in the case of sudden death of an agent her debt is repayed or her deposit is taken by the insurance company. The banks keep deposits of agents under the same interest rate as loans for the firms because of the no-arbitrage condition. But we do not require the balance between agents' savings and firms' loans. Moreover, it will be seen that such requirement is not needed in our model for determining a general equilibrium and could make the growth impossible.

A substantial novelty of the proposed model is that it is a hybrid of continuous time OLG model and growth model with a continuum of consumption goods. The main result is that for the agents' savings alone may be not enough for growth. Additional money is needed, which is provided by banks. One can interpret this money as a negative bubble. It is proven that aggregated assets of agents are bounded while the total value of intellectual property in the economy with homogeneous consumption can grow unboundedly so the difference between agents' savings and the value of patents can also be unlimited. The heterogeneity of consumption (discounting old goods) brings qualitative difference in the model dynamics compared to the homogenous case. The heterogeneity can make the total value of patents be bounded with zero limit, thus reducing the imbalance between savings of agents and the value of patents. The growth of the lifetime discounted utility of agents' generations could be bounded in the heterogeneous case in contrast to the case of homogeneous consumption, where the growth of utility is unbounded. It means that in the long run agents preferring new goods do not appreciate further increase of the variety of goods. In the case of homogeneous consumption we prove that the real interest rate tends to zero which is the *biological interest rate* (the population growth rate which is zero in the long run), see Samuelson (1958). While the general equilibrium with heterogeneous consumption can be inefficient and the real interest rate can become negative as it may happen in OLG models (e.g., Blanchard, 1985; Diamond, 1965). We observed that in both heterogeneous and homogeneous cases the variety of goods can grow unboundedly.

Main results are published in Belyakov, Haunschmied, and Veliov (2014, 2012).

References

Belyakov, A., Haunschmied, J., & Veliov, V. (2012). *General equilibrium model with horizontal innovations and heterogeneous products* (Research Report No. 2012-01). Operations Research and Control Systems, Institute of Mathematical Methods in Economics, Vienna University of Technology. Retrieved from `http://orcos.tuwien.ac.at/fileadmin/t/orcos/Research_Reports/2012-01_Bely-VV-HS.pdf`

Belyakov, A., Haunschmied, J., & Veliov, V. (2014). Heterogeneous consumption in olg model with horizontal innovations. *Portuguese Economic Journal*, *13*(3), 167-193. doi: 10.1007/s10258-014-0105-7

Blanchard, O. (1985). Debt, deficits and finate horizons. *Journal of Political Economy*, *93*, 223–247.

Boucekkine, R., de la Croix, D., & Licandro, O. (2002). Vintage human capital, demographic trends, and endogenous growth. *Journal of Economic Theory*, *104*(2), 340 - 375.

Cass, D., & Yaari, M. E. (1967). Individual saving, aggregate capital accumulation, and efficient growth. In K. Shell (Ed.), *Essays on the theory of optimal economic growth* (p. 233-268). Cambridge, MA: MIT.

d'Albis, H. and Augeraud-Véron, E. (2011). Continuous-time overlapping generations models. In R. Boucekkine, N. Hritonenko, & Y. Yatsenko (Eds.), *Optimal control of age-structured population in economy, demography, and the environment. routledge explorations in environmental economics* (pp. 45–69). Taylor and Francis.

Diamond, P. A. (1965). National debt in a neoclassical growth model. *American Economic Review*, *55*, 1126–1150.

Gale, D. (1973). Pure exchange equilibrium of dynamic economic models. *Journal of Economic Theory*, *6*, 12–36.

Jones, C. I. (1995a). R&d-based models of economic growth. *Journal of Political Economy*, *103*, 759–784.

Jones, C. I. (1995b). Time-series tests of endogenous growth models. *Quarterly Journal of Economics*, *110*, 495–525.

Judd, K. L. (1985). On the performance of patents. *Econometrica*, *53*, 567–585.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*, 71–102.

Samuelson, P. A. (1958). An exact consumption-loan model of interest with or without the social contrivance of money. *Journal of Political Economy*, *66*, 467–482.

Sorger, G. (2011). Horizontal innovations with endogenous quality choice. *Economica*, *78*(312), 697–722. doi: 10.1111/j.1468-0335.2010.00852.x