

Designing Aid Programs for Small Open Economies (Draft)*

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Abstract

Using a growth model with entrepreneurial innovation and physical capital accumulation, we assess how the design of foreign aid program may affect the economic transition in receiver countries. The results highlight the importance of transitional dynamics in analyses of economic policy. We find that foreign aid programs aimed at innovation are more efficient in the long run than subsidies to physical capital investment, provided the number of different products is below the optimal level chosen by the social planner. However, the adjustment speed to the new steady state is higher when the subsidy to physical capital investment is applied instead of the subsidy to innovation. The high adjustment speed has a positive impact on private consumption in the short to medium term, and the ranking of instruments in terms of welfare may therefore change.

Keywords: growth, development aid, transitional dynamics

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1 Introduction

Since the collapse of the communist regimes in eastern Europe, foreign aid programs have been established to ease the transition from planning to market economies. For example, the Nordic countries and Germany are active supporters of the economic development in the Baltic states and Poland, and the extent of the help from these donor countries corresponds in scale to the Marshall help given by the United States to Scandinavia after World War II. However, the impact of foreign aid on income, growth and welfare in receiving countries is not clear.

We assess how the design of foreign aid programs may affect the economic transition in receiver countries, and evaluate the welfare effects of subsidies to (i) entrepreneurial innovation, (ii) research and development, (iii) foreign direct investment, (iv) physical capital investment, (v) imports, and (vi) private consumption. To analyze these issues, we apply a growth model that represents a small open economy with research and development activities and physical capital accumulation. The dynamic transition is modeled explicitly, which is different from analyses of growth and welfare that are based on the steady state or balanced growth equilibrium, see for example Grossman and Helpman (1991), Romer (1990), Segerstrom (2000), Segerstrom and Zolnierak (1999). These long run endogenous growth models are normally designed without physical and human capital formation, and they are not suitable to analyze transitional growth and welfare effects of foreign aid programs to eastern European countries, for example.

Two models are applied in our analysis: (i) an analytical model that represents the long run balanced growth path, and (ii) a numerical model that extends the analytical framework and includes the dynamic transition from the initial steady state to a new long run equilibrium. The results suggest that the transition matters in welfare analyses of foreign aid programs. When the analytical steady state model is applied, we show that foreign aid programs aimed at research and development activities are more efficient than subsidies to physical capital investment, provided the number of different products is below the optimal level preferred by the social planner. This may not be the case in the numerical model, however, where transitional effects are taken into account. If the supply elasticity of new designs is sufficiently low, then it may be more efficient to subsidize investment in physical capital that enters the variable cost structure in intermediate goods production. Although the subsidy to innovation in new products is the most efficient instrument in the new steady state, the subsidy to physical capital

investment has a more significant impact on private income and consumption in the short to medium term. The results thus highlight the importance of transitional dynamics in analyses of economic policy.

The analytical model follows Rivera-Batiz and Romer (1991), Barro and Sala-i-Martin (1995, Chapter 6), and Romer (1994). Instead of applying an endogenous growth model, we assume that the long run growth rate is equal to the exogenous growth rate in the rest of the world, which is consistent with a small open economy framework. Final goods are produced by a composite of labor and intermediate goods, where the latter input factor is composed of a number of complementary varieties. Hence, a larger number of different intermediate products has a positive impact on total factor productivity in the final goods sector. The final goods sector thus demands all available varieties of intermediate products in the economy, which provides an incentive to develop new designs. Innovation takes place in a separate sector where the technology transforms final goods and sector-specific labor (talent or human capital) into blueprints. When a new design is developed, the patent is sold to an intermediate firm that produces the new product using final goods and physical capital. Property rights are secured by patents, and technological progress is therefore a result of market driven research and development. Market power for intermediate firms is accordingly needed to ensure demand for new designs, and we assume that monopolistic competition prevails in the intermediate sector while perfect competition takes place in the rest of the economy. This assumption generates a market failure in the model, which gives the government an incentive to intervene in the intermediate goods market.

We focus mainly on subsidies to entrepreneurial innovation and physical capital investment, ie. policies that strengthen private incentives to invest in new products and production techniques. At this point, we are less concerned about a subsidy to the production of existing intermediate goods, which is the first best policy from the social planner's viewpoint, since this instrument is rarely used in foreign aid programs.

The main result from the analytical model is established in two propositions. These propositions are based on the steady state welfare effects of subsidies to entrepreneurial innovation and physical capital investment. The subsidy to innovation increases the incentive to develop new intermediate products, which raises total factor productivity in the final goods sector and thus welfare. The subsidy to physical capital investment, on the other hand, reduces unit costs in the production of existing intermediate goods, which

increases the equilibrium quantity of existing designs and welfare. Proposition 1 shows that the former effect dominates when the relative importance of sector-specific labor in the research and development sector is sufficiently small, whereas Proposition 2 shows that this critical value is never reached if the subsidy to entrepreneurial innovation leads to a smaller number of intermediate varieties compared to the first best solution. Hence, the subsidy to physical capital investment can only be more efficient if the subsidy to entrepreneurial innovation is too large.

The computable general equilibrium model in the second part of the paper is based on the numerical model developed by Rutherford and Tarr (2000). Compared to their model, we remove the endogenous growth feature by introducing sector-specific labor in the production of blueprints, since the endogenous growth version of the theoretical model in general does not support a steady state general equilibrium. Apart from modeling the transition explicitly, the numerical model extends the theoretical model in two ways. First, we distinguish between domestic and foreign types of intermediate products, and second, domestic and foreign produced final goods are imperfect substitutes. These extensions allow us to analyze a broader selection of instruments that take the origin of capital ownership and products into account.

We find that the elasticity of supply for new designs may change the ranking of instruments. Since producers of intermediate products have market power, the subsidy to physical capital investment is more efficient than the subsidy to innovation for sufficiently low values of the supply elasticity for new designs. However, transitional effects may also influence the ranking of instruments since private consumption profiles are different across the two instruments. The results suggest that the adjustment speed to the new steady state is higher when the subsidy to production of intermediate goods is applied instead of the subsidy that adds new designs to the existing number of intermediate products. The high adjustment speed has a positive impact on private consumption in the short to medium term, and welfare may therefore increase if the subsidy to entrepreneurial innovation is replaced by the subsidy to physical capital investment.

2 Analytical Framework

In this section the analytical framework is presented. The model consists of a final goods sector, an intermediate sector, and a R&D sector. Final

goods are produced by using labor and intermediate input. The latter factor is composed of a number of complementary varieties that are produced by transforming final goods using physical capital. This implies that the final goods sector demands all varieties available to the economy, which thereby creates an incentive to develop designs for new intermediate firms. Innovation is undertaken in a separate sector by using final output and talent. When a new design is created, the patent is sold to a new intermediate firm. In order to ensure demand for patents, market power is required in intermediate firms, which generates a distortion and thereby calls for policy intervention.

2.1 Final Goods Sector

Final goods are produced according to

$$Y = \left[\int_0^N x_j^\alpha dj \right] L^{1-\alpha}, \quad 0 < \alpha < 1, \quad (1)$$

with $j \in [0, N]$. Y is the quantity of final goods, x_j is the quantity of intermediate variety j , L is labor input used in the sector, N is the stock of different intermediate designs, and α is the capital share. The aggregate quantity of intermediate input equals $\int_0^N x_j dj$, whereas effective physical capital is given by the square bracket in (1). Consequently, the larger the number of intermediate designs, the higher is the productivity of a given aggregate quantity of intermediate input. Below it is shown that the demand for intermediate goods is symmetric over varieties. This implies that total factor productivity is given by $N^{1-\alpha}$, since the aggregate quantity of intermediate input is given by $n\bar{x}$.

The demand for the j 'th intermediate variety and labor equals

$$x_j = \left(\frac{\alpha}{p_j} \right)^{\frac{1}{1-\alpha}} L \quad (2)$$

$$L = \frac{(1-\alpha)Y}{w_L}, \quad (3)$$

respectively, assuming perfect competition and profit maximizing behavior. p_j is the price of one unit intermediate variety j and w_L is the wage rate of labor. The final goods price is used as numeraire, i.e. $p_Y = 1$.

2.2 Intermediate Sector

To start activities an intermediate firm issues shares in order to finance the patent that is required for production. Furthermore, property rights are completely secured by patents and monopolistic competition applies. Profit is paid to shareholders as dividends.

An intermediate firm possesses the property right to intermediate variety j and produces according to:

$$x_j = \varphi y_{x_j}^\xi k_j^{1-\xi}, \quad (4)$$

where y_{x_j} is final good input and k_j is physical capital input in the production of intermediate variety j .

The demand for final goods and physical capital in intermediate firm j equals:

$$k_j = (1 - \xi) \frac{uc}{r_K} x_j \quad (5)$$

$$y_{x_j} = \xi uc x_j, \quad (6)$$

respectively, assuming cost minimizing behavior. r_K is the user cost for physical capital and uc is unit costs of producing one unit of intermediate goods. The former cost equals $r_K = r + \delta$ where r is the rate of return and δ is the depreciation rate of physical capital. The latter cost equals $uc = (r + \delta)^{1-\xi}$ assuming $\varphi = \xi^{-\xi} (1 - \xi)^{-(1-\xi)}$. It is evident that unit costs are independent of intermediate type j .

The profit,

$$\pi_{x_j} = (p_j - uc) x_j,$$

is maximized subject to (2), resulting in the intermediate price $p_j = \bar{p} = uc/\alpha$, which is independent of intermediate type j . This also implies symmetric market-clearing quantity

$$\bar{x} = \alpha^{\frac{2}{1-\alpha}} uc^{-\frac{1}{1-\alpha}} L, \quad (7)$$

input quantities $\bar{k} = k_j$ and $\bar{y}_x = y_{x_j}$, and a profit level, $\pi_j = \bar{\pi}$.

The usual non-arbitrage condition for financial capital applies:

$$r = \frac{\dot{p}_N}{p_N} + \frac{\bar{\pi}}{p_N}, \quad (8)$$

where p_N is the patent price. A dot above a variable indicates a time derivative. r is given by a dividend plus a capital gain.

2.3 R&D Sector

Final goods and talent are employed in the production of new designs or blueprints. The development in the stock of designs is assumed to follow:

$$\dot{N} = \beta B^\gamma E^{1-\gamma}, \quad (9)$$

where E is input of talent and B is the quantity of final goods employed in the sector.¹

The demand for final goods and talent in the sector equals:

$$E = (1 - \gamma) w_E^{-\gamma} \dot{N} \quad (10)$$

$$B = \gamma w_E^{1-\gamma} \dot{N}, \quad (11)$$

respectively, assuming profit maximizing behavior and perfect competition. w_E is the wage rate of talent. These demand functions result in a patent price that equals

$$p_N = w_E^{1-\gamma}, \quad (12)$$

when $\beta = \gamma^{-\gamma} (1 - \gamma)^{-(1-\gamma)}$.

2.4 Household

The household sector is characterized by a representative household with an infinite time horizon. Intertemporal preferences are described by the isoelastic utility integral

$$U = \int_0^\infty e^{-\rho t} \frac{C^{1-\theta} - 1}{1-\theta} dt. \quad (13)$$

$\rho > 0$ is the rate of time preference, $\theta > 0$ is the inverse intertemporal elasticity of substitution, and C is consumption of final goods. U is maximized subject to the dynamic budget constraint:

$$\dot{F} = w_L L + w_E E + rF - C, \quad (14)$$

where F is financial capital invested in physical capital and shares in intermediate firms.

¹Discuss talent: What we mean is human capital.

Discuss: The R&D technology could included knowledge spillovers: $\dot{N} = \beta B^\gamma E^{1-\gamma} N^\omega$, with $0 < \omega < 1$.

The growth rate in consumption is derived to

$$g_C = \frac{1}{\theta}(r - \rho) \quad (15)$$

by applying the first-order condition for C and F . g_C indicates the growth rate of C .

2.5 Market Clearing

The equilibrium conditions for the N intermediate markets are already imposed on the model. Furthermore, the markets for talent, labor, and physical capital clear. The equilibrium condition for the final goods market is derived by rewritten (14) using $F = N(p_N + \bar{k})$ and (1), (3), (5), (6), (7), (8), (10), and (11):

$$Y = C + I + Y_x + B \quad (16)$$

where $K = N\bar{k}$ is the aggregate stock of physical capital, $Y_x = N\bar{y}_x$ is aggregate input of final goods in the intermediate sector, and $I = \dot{K} + \delta K$ is aggregate gross-investments in physical capital. Finally, the patent market clears according to Walras' Law.

3 Steady-State Welfare Effects

In the following a small open economy framework is applied. In steady-state equilibrium this implies that both the interest rate and the growth rate are given from abroad.² For simplicity labor and talent are treated exogenously in the model. Two cases are investigated. First, we assume that labor, L , is constant, whereas talent, E , increases by a constant growth rate. Given this assumption it can be shown that there is no growth in output in relation to talent in steady-state equilibrium, i.e. $g_{Y/E} = 0$. Consequently, Y/E is constant implying that the model is an exogenous growth model. Second, talent, E , and labor, L , increase by a constant growth rate. In this case output in relation to both talent and labor are growing in steady-state equilibrium, i.e. $g_{Y/E} = g_{Y/L} = g/(1 - \gamma)$. This implies that the model is a semi-endogenous growth model since long-run economic growth is driven

²This assumption has no implications for the steady-state analysis because the same steady-state results are established when a closed economy framework is applied.

by an exogenous growth process and still income per capita grows. We do not analyze the endogenous growth version of the model, i.e. $\gamma = 1$. The explanation is that this version of the model does not support a steady-state equilibrium in general. This is shown in Appendix A, where the three different versions of the growth models are discussed.

Monopoly rights in inventions generate space for welfare improving policy interventions. The distortion implies that the demand for intermediates is below the efficient quantity that arises for a price equal to unit costs. Therefore, subsidies to purchases of intermediate goods correct for the inefficiency. A subsidy that covers a share $(1 - \alpha)$ of intermediate goods purchases remove the inefficiency generated by monopoly pricing. This brings the economy to the equilibrium chosen by a social planner maximizing utility of the representative household.

In this section, steady-state welfare effects from two different foreign financed subsidies are investigated. These are R&D subsidies and investment subsidies that affect user costs of physical capital. These subsidies are second-best instruments to correct for monopoly pricing in the intermediate sector. The reason that only second-best policies are analyzed is that we want to focus on policy instruments that are being applied in actual aid programs for transition economies. Such instruments are to a great extent covered by subsidies analysed in this paper. The reason that R&D- and investments subsidies are studied in this section is that we want to focus on policies that strengthens the incentives to invest.

The R&D subsidy covers a cost share, S_R , of final goods used in R&D activities. This changes the patent price in (12) to

$$p_N = w_E^{1-\gamma} (1 - S_R)^\gamma. \quad (17)$$

The investment subsidy covers a cost share, S_K , of physical capital investments. This reduces the price of investments to $(1 - S_K)$. Consequently, user costs are reduced and thereby unit costs

$$uc = ((1 - S_K)(r + \delta))^{1-\xi}. \quad (18)$$

Hence, the R&D subsidy affects fixed costs, whereas the investment subsidy affects variable costs in intermediate firms.

It is evident from (17) that the higher is γ , the more effective is the R&D subsidy on patent prices. The explanation is that γ is the cost share of final goods in innovation. Hence, the more important is final goods in R&D,

the more effective is subsidies to this activity. The higher is the cost share of physical capital in intermediate production, $(1 - \xi)$, the more effective is the investment subsidy. Therefore, the more important is physical capital in intermediate production, the more effective is the investment subsidy. This is seen from (18).

Furthermore, the two subsidies affect the equilibrium condition for the final goods market such that:

$$S_R B + S_K I + Y = C + I + Y_x + B. \quad (19)$$

The left hand side of (19) shows final goods available to the domestic economy, which consists of foreign transfers beside output of the domestic final goods sector. The transfers are divided into support to R&D, $S_R B$, and support to investments in physical capital, $S_K I$.

Below steady-state welfare effects from the two subsidies are compared. The policy analysis is performed by two experiments. In the first experiment the R&D subsidy is implemented with no investment subsidy, i.e. $S_R > 0$, $S_K = 0$, whereas the investment subsidy is implemented with no R&D subsidy in the second experiment, i.e. $S_R = 0$, $S_K > 0$. The analysis is performed in two steps. In the first step, the restriction that foreign transfers are of the same size in the two experiments is imposed on the analysis, i.e. $S_R B = S_K I$. This restriction is applied to derive the relationship between the subsidies in the two experiments. In the second step, the steady-state consumption level is derived with the implementation of subsidies, which is used to derive long run consumption elasticities with respect to the subsidies. In this part of the analysis the restriction from the first step is taken into account.

First, the restriction $S_R B = S_K I$ is used to express the subsidy in the first experiment, S_R , as a function of the subsidy in the second experiment, S_K .

$$S_R = \frac{\alpha (1 - \xi) S_K}{\gamma (1 - \alpha) t (1 - S_K)^{\frac{1 - \xi \alpha}{1 - \alpha}} + \alpha (1 - \xi) S_K}, \quad (20)$$

where t is a constant below 1.³ This expression is derived after substitution of (11) and (5) into the restriction. The elasticity between instruments is

³ $t = (g/r) (r + \delta) / (g + \delta) < 1$ for $g_E = g$, $g_L = 0$. For $g_E = g_L = g$, $t = ((g' - g) / (r - g)) (r + \delta) / (g' + \delta) < 1$ where $g' = g / (1 - \gamma)$.

derived after log differentiation of (20):

$$\frac{\partial \ln S_K}{\partial \ln S_R} = \frac{1}{(1 - S_R)} \frac{(1 - \alpha)(1 - S_K)}{1 - \alpha + \alpha(1 - \xi)S_K}.$$

This elasticity expresses how much the investment subsidy, S_K , imposed in the second experiment have to increase to satisfy that $S_R B = S_K I$ when the R&D subsidy, S_R , of the first experiment increases by one percent.

Second, steady-state welfare is expressed using steady-state consumption, see (13). Steady-state consumption equals:

$$C = (1 - S_K)^{\frac{-\alpha(1-\xi)}{(1-\alpha)(1-\gamma)}} (1 - S_R)^{-\frac{\gamma}{1-\gamma}} \text{deter}, \quad (21)$$

after implementation of subsidies. This expression is derived using (19). ‘deter’ is a deterministic term independent of subsidies. The elasticity of steady-state consumption in the first experiment with R&D subsidies is derived to

$$\alpha_{S_R} = \frac{\partial \ln C|_{S_R>0, S_K=0}}{\partial \ln S_R} = \frac{1}{(1 - \gamma)(1 - S_R)} \gamma S_R,$$

whereas the elasticity in the second experiment with the investment subsidy is derived to

$$\alpha_{S_K} = \frac{\partial \ln C|_{S_R=0, S_K>0}}{\partial \ln S_K} \frac{\partial \ln S_K}{\partial \ln S_R} = \frac{1}{(1 - \gamma)(1 - S_R)} \frac{\alpha(1 - \xi)S_K}{1 - \alpha + \alpha(1 - \xi)S_K},$$

by using (20) and (21).

α_{S_K} expresses the percentage increase in steady-state consumption in the second experiment when the investment subsidy increases according to $\partial \ln S_K / \partial \ln S_R$. In other words, the increase in S_K in the second experiment is related to increase in S_R in the first experiment such that the restriction that foreign transfers equal in the two experiments, i.e. $S_R B = S_K I$.

It is seen that both α_{S_R} and α_{S_K} are positive and increasing for all $0 \leq S_R, S_K \leq 1$. This is because a higher aid level always improves welfare. The important question, however, is which of the two subsidies have the largest impact on welfare. This question is discussed in the two propositions below. The overall result is that steady-state welfare increases more with R&D subsidies as long as the subsidy level is below or equal to the level that ensures an efficient number of intermediate varieties in the market solution.

The efficient number of intermediate varieties is given by the choice made by a social planner maximizing utility of the representative household.

The two elasticities shown above lead to the following proposition for steady state welfare effects from supporting the creation of new intermediate firms compared to the effects from supporting production in existing intermediate firms:⁴

Proposition 1 *The sign of $\alpha_{S_R} - \alpha_{S_K}$ depends on the parameters in the three production functions, α , γ , ξ :*

- (i) *When $\gamma/(1-\gamma) > (1-\xi)\alpha/(1-\alpha)$, $\alpha_{S_R} - \alpha_{S_K} > 0$ for $S_K \in (0, 1)$.*
- (ii) *When $\gamma/(1-\gamma) \leq (1-\xi)\alpha/(1-\alpha)$, $\alpha_{S_R} - \alpha_{S_K} \geq 0$ for $S_K \in (0, \bar{S}_K)$, where $\bar{S}_K \leq 1$. For $S_K > \bar{S}_K$, $\alpha_{S_R} - \alpha_{S_K} < 0$*

Proof. See Appendix B. $\square$

Proposition 1 shows the effect on steady-state consumption from a marginal increase in the R&D subsidy in relation to the effect of a comparable increase in the investment subsidy. If $\gamma/(1-\gamma)$ is above the critical value, $(1-\xi)\alpha/(1-\alpha)$, the R&D subsidy always leads to larger increase in steady-state consumption. However, if $\gamma/(1-\gamma)$ is below this value, the effect of the investment subsidy exceeds that of the R&D subsidy given that the investment subsidy is above a critical value, $\bar{S}_K$.

The explanation for the sign to be ambiguous for a relatively low γ is the following: The R&D subsidy increases the incentive to innovate, which increases the productivity and thereby welfare. The lower is cost share of final goods in innovation, γ , the lower is the importance of the R&D subsidy, see (17). The investment subsidy lowers user costs and, thereby, unit costs in intermediate production. This increases the equilibrium quantity of intermediate goods and thereby welfare. The higher is the cost share of physical capital, $(1-\xi)$, the higher is the importance of the investment subsidy, see (18). Therefore, the lower the relative size of γ , the lower is the productivity effect from the R&D subsidy relative to the effect from the investment subsidy. Below the critical γ level the effect from the R&D subsidy is so low that the investment subsidy has larger impact on output at high subsidy levels.

The cost share of intermediates in final goods production, α , also influences the result established in Proposition 1. The higher is α the more likely

⁴In the propositions we refer to S_K only instead of using both S_K and $S_R = S_R(S_K)$.

is $\gamma/(1-\gamma) \leq (1-\xi)\alpha/(1-\alpha)$ to apply. The reason is that α measure complementarity between intermediate varieties. A rise in α , lower the productivity effect from new blueprints, which thereby reduces the importance of R&D subsidies.

In Proposition 2, the unambiguous result (ii) of Proposition 1 is developed further:

Proposition 2 $\alpha_{S_R} > \alpha_{S_K}$ for $S_K \in (0, S_K(S_R^*))$ when $\gamma/(1-\gamma) \leq \alpha(1-\xi)/(1-\alpha)$. $S_R^* = 1 - \alpha^{1/(1-\alpha)}$ is the R&D subsidy that ensures a number of intermediate varieties in the market solution equal to the number a social planner would choose.

Proof. See Appendix B. $\square$

Proposition 2 shows that the effect on steady-state welfare of a marginal increase in the R&D subsidy exceeds the effect of a comparable marginal increase in the investment subsidy when $\gamma \leq \alpha(1-\xi)/(1-\alpha\xi)$; as long as the number of intermediate varieties does not exceed the number a social planner would choose.

The combined result of the two propositions is that the steady-state welfare effect of subsidies covering a share of the fixed costs in intermediate firms are larger than subsidies covering a share of the variable costs in intermediate firms; as long as the subsidy level does not exceed the level chosen by the social planner.

4 Transitional Dynamics

To assess potential welfare effects of foreign aid programs, we develop a computable general equilibrium model that extends the theoretical framework and is based on the numerical model developed by Rutherford and Tarr (2000). The results with the analytical model are invariant between trend growth in labor supply and productivity, and we adopt a numerical model with a constant growth rate in labor supply and introduce a fixed factor (rents) in the production of blueprints that grows at the same rate.

4.1 Extensions of the Theoretical Model

Apart from modeling the transition explicitly, the numerical model extends the theoretical framework in five ways.

First, domestic and imported final goods are imperfect substitutes, and imported final goods cannot be produced in the home market due to technical limitations of the domestic final goods sector. The intratemporal (or instantaneous) utility function is accordingly represented by a Cobb-Douglas function with domestic and imported final goods as arguments.

Second, final goods are produced as differentiated products for sale in the domestic and international markets. Transformation possibilities between domestic and export sales for a given composite output level are represented by a constant elasticity of transformation (CET) function:

$$Y_t = Y_0 \cdot \left[\eta_D \left(\frac{D_t}{D_0} \right)^{(1+\eta)/\eta} + (1 - \eta_D) \left(\frac{E_t}{E_0} \right)^{(1+\eta)/\eta} \right]^{\eta/(1+\eta)}$$

where D is domestic sales, E is export sales, η is the elasticity of transformation and η_D is the baseline value share of domestic sales. A subscript zero indicates base year levels of output to domestic and export markets. Domestic producers of final goods maximize profits subject to the CET constraint, which determines optimal shares of sales at home and abroad.

Third, we distinguish between domestic and foreign producers of intermediate goods. Hence, production of final output in (1) is now represented by:

$$Y = \left[\int_0^{N_D} x_{jD}^\alpha dj + \int_0^{N_F} x_{jF}^\alpha dj \right] \cdot L^{(1-\alpha)} \quad (22)$$

where time subscripts are dropped for convenience, while subscripts D and F denote domestic and foreign producers. The total number of active intermediate firms in the small open economy, N , is equal to the sum of N_D and N_F .

Fourth, we distinguish between domestic and imported final goods in the variable cost component of intermediate goods production. The production technology in (4) is modified to be represented by a Cobb-Douglas function with the two types of final goods and firm specific physical capital as arguments, and marginal costs of production exhibit constant returns to scale in both domestic and foreign types of intermediate firms.

Fifth, the fixed cost component of intermediate goods production is divided into two parts and may be different across domestic and foreign types of firms: (i) an “overhead,” which occurs as a fixed recurring cost in the production of intermediate goods, and (ii) a “setup” cost, which is a one-time research and development cost that must be incurred in order to design and market a new product. The fixed overhead cost is used on domestic final goods, and we distinguish between inputs of domestic and imported final goods in the production of new designs. The technology in the production of new designs is represented by a Cobb-Douglas function with a fixed factor and innovation inputs as arguments, where innovation inputs include domestic and imported final goods in fixed proportions.

The production function for final goods is perfectly symmetric with respect to intermediate inputs from domestic and foreign firms, which implies firm level product differentiation with no brand or national preferences. Varieties of different vintages are equally preferred but differentiated, and all domestic and foreign firms in the economy sell identical quantities at identical prices if the cost structure is the same across the two types of firms. Domestic and foreign firms may have different cost structures, however, and production levels and prices may therefore differ across the two types of firms.

4.2 Welfare effects of foreign aid programs

We apply a symmetric version of the model to assess the welfare effects of various policy instruments.⁵ Cost structures and ownership shares are identical across domestic and foreign firms, and we assess the welfare effects of subsidies to entrepreneurial innovation (E), research and development (R&D), foreign direct investment (FDI), investment in new physical capital (K), imports (M), and private consumption (C). The foreign aid program amounts to one percent of GDP in the receiving region, which corresponds to the current level of foreign aid given by international donors to the Baltic states.

The symmetric model provides a useful benchmark, and we next analyze the welfare implications of changing the cost structures and ownership shares in domestic and foreign firms. We find that two parameters in particular are important to the results: (i) the allocation of fixed costs between overhead in the production of intermediate goods and setup costs in the production of new

⁵We use GAMS/MPSGE to solve the model numerically, and the code is provided in the Appendix. Rutherford (1995, 1999) documents this modeling system and software.

designs, and (ii) the value share of the fixed factor (rents) in the production of blueprints, which is negatively correlated with the supply elasticity for new designs.

To assess the economic impacts of the policy reforms, the simulated policy changes are compared with a baseline simulation reflecting the initial steady state. The symmetric benchmark model is calibrated to the dataset presented in Table 1, where the distribution of value added across labor and capital income and the distribution of domestic output across domestic and export markets correspond to popular values in applied general equilibrium models. Domestic and foreign firms in the intermediate goods sector have equal market shares and identical technologies, and the elasticity of supply for blueprints is equal to one. Finally, the elasticities of substitution in utility and production functions follow the model in Rutherford and Tarr (2000).

Table 2a shows that the general subsidy to entrepreneurial innovation is the most efficient instrument when cost structures and ownership shares are symmetric across firms; the present value of intertemporal domestic income increases by 4.2 percent compared to the business as usual (BaU) scenario. The general subsidy to innovation is levied on inputs of domestic and imported final goods in the production of new designs in both types of firms, while the subsidies to research and development and foreign direct investment are levied on similar inputs in respective domestic and foreign firms. Subsidies to research and development and foreign direct investment yield identical welfare effects, but they are less efficient compared to the general subsidy to innovation because the allocation of resources across firm types is distorted.

Welfare increases by 3.4 percent if foreign aid instead is allocated to the subsidy in physical capital, and the instrument is less efficient compared to any of the innovation instruments. The results thus indicate that it is more optimal to subsidize the production of new products instead of the production of existing intermediate goods where physical capital enters. A small fraction (6 percent) of imported final goods enter the production of new designs, and welfare increases by 1.8 percent when the subsidy is levied on these goods. The subsidy to private consumption corresponds to a lump sum tax, but the welfare impact of subsidizing private consumption is larger than the one percent income transfer and equal to 1.3 percent because the income effect has a positive impact on the number of intermediate products.

Figure 1 illustrates the percentage change from benchmark private consumption during the first 50 periods of the model time horizon when foreign aid is allocated to entrepreneurial innovation and physical capital investment. Private consumption is consistently higher during the transition when the subsidy to entrepreneurial innovation is applied instead of the subsidy to physical capital investment. Figure 2 shows that the subsidy to innovation is more efficient in creating new designs than the subsidy to physical capital investment. However, Figure 3 illustrates that the average production of existing intermediate products falls when the subsidy to innovation is applied, because the number of new designs increases significantly. The positive welfare impact from new designs is more significant than the negative welfare impact from the reduced average production of intermediate products, and it is more efficient in terms of welfare to apply the subsidy to innovation instead of the subsidy to physical capital investment.

In the second experiment, the elasticity of supply with respect to new domestic and foreign designs is reduced from 1 percent to 0.15 percent. Hence, the three innovation instruments that subsidize inputs of final goods in the production of new designs are less efficient compared to the benchmark model, and Table 2a shows that welfare increases by 2.5 percent when foreign aid is allocated to entrepreneurial innovation. The reduction in welfare is smaller when the subsidy to physical capital investment is applied because the subsidy is levied on variable costs in the production of existing intermediate goods. Since producers of intermediate products have market power, the subsidy to physical capital investment is more efficient than the subsidy to innovation for sufficiently low values of the supply elasticity for new designs. Transitional effects may also influence the ranking of instruments, because private consumption profiles are different across the two instruments. Figure 4 shows that the subsidy to innovation in new products is the most efficient instrument in the long run, but the subsidy to physical capital investment has a larger impact on private consumption in the short to medium term. The increase in private consumption in the short to medium term is more significant than the long term impact, and the transitional effects imply that the subsidy to physical capital is more efficient than the subsidy to innovation.

Figure 5 illustrates that the subsidy to innovation remains more efficient in creating new firms than the subsidy to physical capital investment when the supply elasticity of new designs falls from 1 to 0.15. Fewer firms are created when the supply elasticity of new designs falls, and the reduction in new firms is more pronounced when foreign aid is allocated to innovation instead of physical capital investment. The reduced number of new de-

signs implies that the production of existing intermediate products increases compared to the scenario with a higher supply elasticity of new designs, see Figure 6. The results suggest that the adjustment speed to the new steady state is higher when the subsidy to production of intermediate goods is applied instead of the subsidy that adds new designs to the existing number of intermediate products. The high adjustment speed has a positive impact on private consumption in the short to medium term, and welfare increases when the subsidy to innovation is replaced by the subsidy to physical capital investment.

The fixed cost component of intermediate goods production is held constant in the third experiment, but the allocation of fixed costs between overhead in the production of intermediate goods and setup costs in the production of new designs is different across the two types of firms. In particular, overhead falls and setup costs increase in domestic firms, while overhead increases and setup costs decrease in foreign firms. Since development costs of new foreign designs are reduced, welfare increases significantly when the subsidy to foreign direct investment is applied compared to the benchmark model with symmetric cost structures. Table 2a shows that welfare increases by 11.9 percent when overhead falls and setup costs increase in domestic firms compared to foreign firms. The welfare effect of the subsidy to research and development in domestic firms falls on the other hand, and the subsidy to entrepreneurial innovation in general is less efficient compared to the benchmark model. [To be added: compare welfare effects of subsidies to innovation and physical capital investment].

Table 2b illustrates that domestic and foreign ownership shares, the import value share in setup costs of new designs, and the distribution of inputs in the production of existing intermediate goods have no significant effects on the ranking of instruments. Complete foreign ownership of multinational companies and no foreign stock holdings in domestic firms only affects the welfare impacts of subsidies to research and development and foreign direct investment. In this case, the subsidy to research and development in domestic firms is more efficient than the subsidy to foreign direct investment, and it is even more efficient than the general subsidy to innovation. However, compared to the benchmark model with symmetric ownership shares, welfare increases by only 0.5 percentage points when foreign aid is allocated to subsidies in domestic research and development.

The import value share in setup costs of new designs is next reduced from 31.2 percent to 25 percent in domestic firms and increased from 31.2 percent

to 37.5 percent in foreign firms. Unit costs in the production of new designs is kept unchanged in the initial steady state, and the value share of domestic final goods is accordingly increases in domestic firms and reduced in foreign firms. The overall impact of changing the cost structure in the production of new designs is very small. Table 2b shows that welfare increases slightly more when the subsidy to research and development is applied instead of the subsidy to foreign direct investment. Hence, the results suggest that it is more efficient to support research and development in sectors with a relatively high demand for domestic final goods. The changing cost structure has no impact on the efficiency of the subsidy to innovation in general since the supply elasticity of new designs is kept unchanged, and the welfare effect of the subsidy to imported final goods unchanged as well because domestic and imported final goods enter the production of new designs in fixed proportions.

Finally, we change the distribution of inputs in the production of existing intermediate goods. In one experiment, the capital value share increases from 37.5 percent to 50 percent in domestic firms and decreases from 37.5 percent to 25 percent in foreign firms. Unit costs in the production of intermediate goods is kept constant in the initial steady state, and the value share of domestic final goods is reduced in domestic firms and increased in foreign firms. The increased value share of domestic final goods in foreign firms implies that the subsidy to foreign direct investment is more efficient than the subsidy to research and development in domestic firms, but the difference in welfare between the two instruments is quite small. Welfare is slightly smaller compared to the benchmark model when physical capital investment is subsidized because physical capital is applied in different proportions across the domestic and foreign firms.

In the last experiment, the import value share decreases from 37.5 percent to 25 percent in domestic firms and increases from 37.5 percent to 50 percent in foreign firms, while inputs of domestic final goods are adjusted to keep unit costs unchanged in the initial steady state. The value share of domestic final goods increases in domestic firms, and the subsidy to research and development in domestic firms is more efficient than the subsidy to foreign direct investment. Welfare decreases marginally compared to the benchmark model when the import subsidy is applied because the import value share is different across domestic and foreign intermediate firms.

5 Conclusions

Using a growth model with research and development activities and physical capital accumulation, we demonstrate that transitional dynamics may play an important role when welfare effects of foreign aid programs to small open economies are evaluated. In particular, a subsidy to entrepreneurial innovation may be more efficient in the long run compared to a subsidy to physical capital investment, when the number of intermediate varieties implied by the subsidy to entrepreneurial innovation is below the optimal level of varieties chosen by the social planner. The reason is that the subsidy to entrepreneurial innovation increases the incentive to develop new intermediate products, which raises total factor productivity in the final goods sector and thus welfare. The subsidy to physical capital, on the other hand, reduces unit costs in the intermediate goods sector, which increases the equilibrium quantity of existing intermediate goods and welfare as well.

This result depends crucially on the supply elasticity of new designs. If the supply elasticity of new designs is sufficiently low, then it may be more efficient to subsidize investment in physical capital that enters the variable cost structure in intermediate goods production. Since producers of intermediate products have market power, the subsidy to physical capital investment is more efficient than the subsidy to innovation for sufficiently low values of the supply elasticity for new designs. Transitional effects may also influence the ranking of instruments, because private consumption profiles are different across the two instruments. The results suggest that the adjustment speed to the new steady state is higher when the subsidy to investment in physical capital is applied instead of the subsidy to new designs. The high adjustment speed has a positive impact on private consumption in the short to medium term, and welfare increases when the subsidy to innovation is replaced by the subsidy to physical capital innovation.

References

- [1] Barro, R.J. and X. Sala-i-Martin (1995), '*Economic Growth*,' New York: McGraw-Hill
- [2] Davidson, C. and P.S. Segerstrom (1998), 'R&D subsidies and Economic Growth,' *RAND Journal of Economics*, 29(3), 548-577
- [3] Grossman, G.M., and E. Helpman (1991), '*Innovation and Growth in the Global Economy*,' Cambridge, MA.: MIT Press
- [4] Lutz, A. (2000)
- [5] Rivera-Batiz, L.A. and P.M. Romer (1991), 'Economic Integration and Endogenous Growth,' *Quarterly Journal of Economics*, 106 (2), 531-555
- [6] Romer, P.M. (1990), 'Endogenous Technical Change,' *Journal of Political Economy*, 98(5), part II, S71-S102
- [7] Romer, P.M. (1994), 'New Goods, Old Theory and the Welfare Costs of Trade Restrictions,' *Journal of Development Economics*, 43(1), 5-38
- [8] Rutherford, T.F. (1995), 'Extensions of GAMS for Complementarity Problems Arising in Applied Economics,' *Journal of Economic Dynamics and Control*, 19, 1299-1324.
- [9] Rutherford, T.F. (1999), 'Applied General Equilibrium Modeling with MPSGE as a GAMS Subsystem: An Overview of the Modeling Framework and Syntax,' *Computational Economics*, 14, 1-46.
- [10] Rutherford, T.F. and D.G. Tarr (2000), 'Trade Liberalization, Product Variety and Growth in a Small Open Economy: A Quantitative Assessment,' University of Colorado, Memo.
- [11] Segerstrom, P.S. (2000), 'The Long-Run Growth Effects of R&D Subsidies,' *Journal of Economic Growth*, 5 (4), 277-305
- [12] Segerstrom, P.S. and J.M. Zolnieriek (1999), 'The R&D Incentives of Industry Leaders,' *International Economic Review*, 40(3), 745-766
- [13] Sørensen, A. (1997), 'Growth-Enhancing Policies in a Small Open Economy,' in J. Fagerberg, P. Hansson, L. Lundberg, and A. Melchior (ed.), '*Technology and International Trade*,' Edward Elgar, 158-78
- [14] Sørensen, A. (1999), 'R&D, Learning, and Phases of Economic Growth,' *Journal of Economic Growth*, 4 (4), 429-445

Table 1. Parameter Values in Numerical Model

Value Shares:

CM0	Import value share in final demand	0.100
CD0	Value share of domestic products in final demand	0.900
E0	Export value share in production of final goods	0.235
D0	Value share of domestic sales in production of final goods	0.765
α	Value share of intermediate goods in production of final goods	0.660
VK0	Capital value share in intermediate production	0.375
MX0	Import value share in intermediate production	0.375
DX0	Value share of domestic final goods in intermediate production	0.250
MK0	Markup revenue in intermediate production	0.340
FC0	Value share of overhead in fixed costs of intermediate production	0.500
IR0	Value share of rents in production of new intermediate designs	0.500
IM0	Import value share in production of new intermediate designs	0.312
ID0	Value share of domestic final goods in production of new intermediate designs	0.188

Other Parameters:

r	Interest rate	0.05
ρ	Rate of time preference	0.05
g	Growth rate	0.02
δ	Capital depreciation rate	0.07
θ	Inverse intertemporal elasticity of substitution	2.00
η	Elasticity of transformation in production of final goods	1.10

Table 2a. Changing cost structures and welfare (EV – percentage change).

	E	RD	FDI	K	M	C
Symmetric cost structures and ownership shares	4.20	3.75	3.75	3.42	1.79	1.32
Supply elasticity for designs (D=0.15 and F=0.15)	2.48	2.28	2.28	2.58	1.47	1.19
Value share of overhead (D=0.10 and F=0.90)	3.65	1.91	11.85	5.08	2.05	1.34

Table 2b. Changing cost structures and welfare (EV – percentage change).

	E	RD	FDI	K	M	C
Symmetric cost structures and ownership shares	4.20	3.75	3.75	3.42	1.79	1.32
Multinational ownership share (D=0 and F=1)	4.20	4.24	3.27	3.42	1.79	1.32
Import value share in I (D=0.250 and F=0.375)	4.20	3.82	3.68	3.42	1.79	1.32
Capital value share in X (D=0.50 and F=0.25)	4.21	3.70	3.81	3.39	1.79	1.32
Import value share in X (D=0.25 and F=0.50)	4.23	4.06	3.50	3.42	1.77	1.30

Figure 1. Consumption – Percentage change from BaU (supply elasticity for new designs = 1.00)

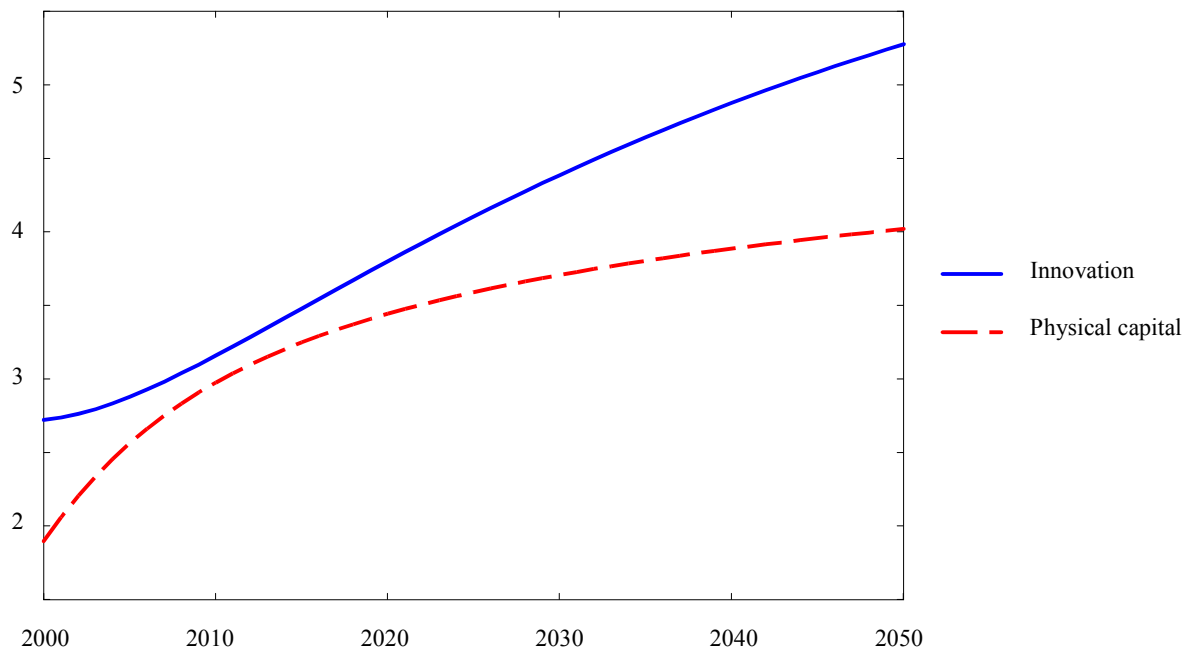


Figure 2. New firms – Percentage change from BaU (supply elasticity for new designs = 1.00)

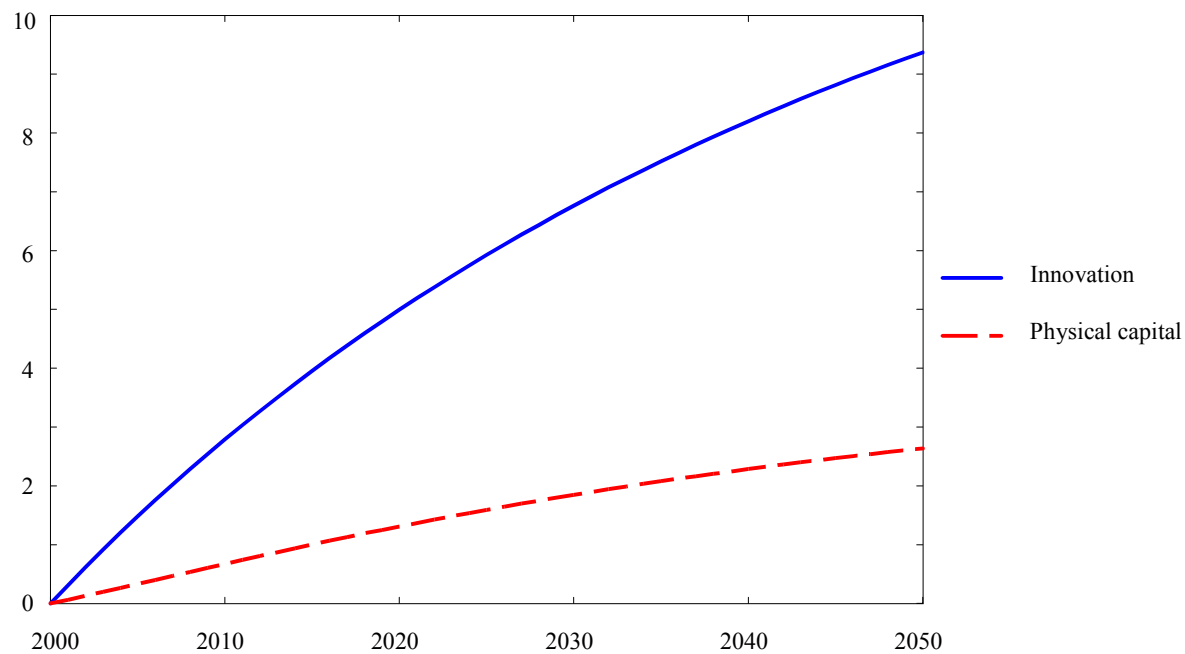


Figure 3. Existing firms – Percentage change from BaU (supply elasticity for new designs = 1.00)

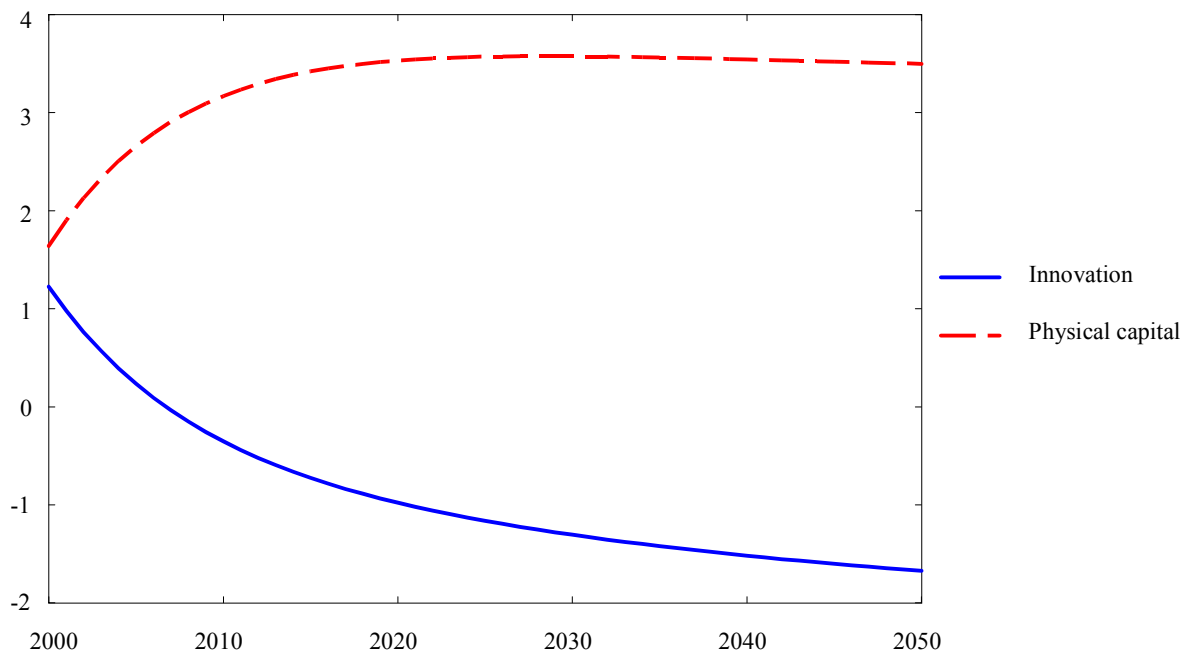


Figure 4. Consumption – Percentage change from BaU (supply elasticity for new designs = 0.15)

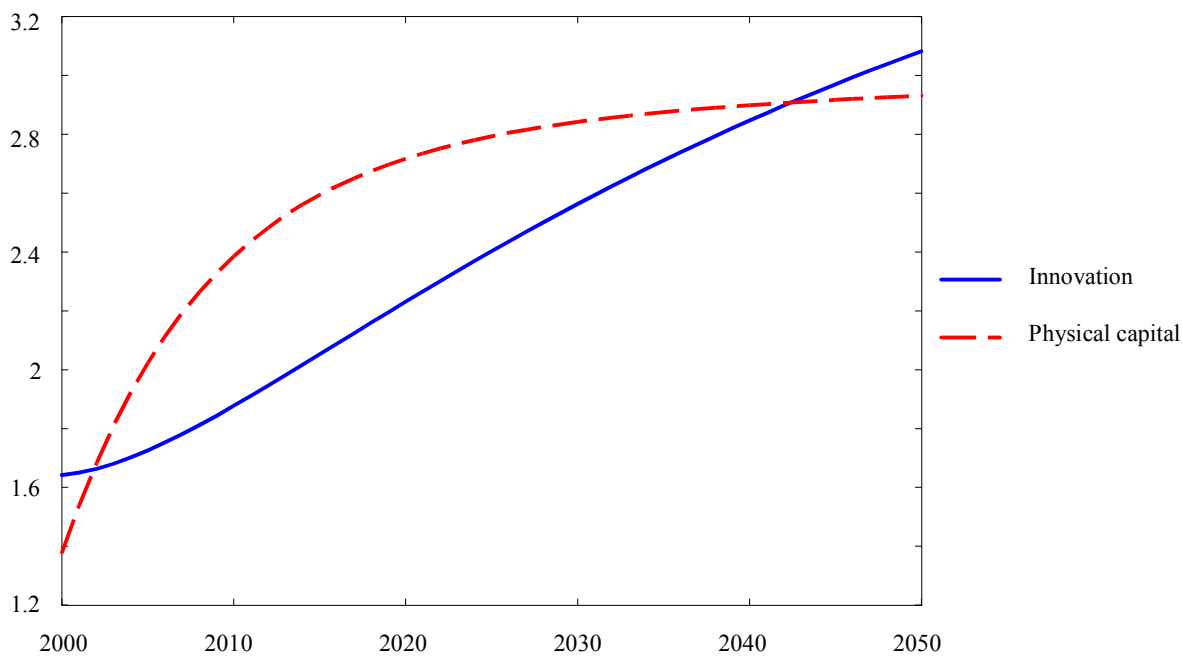


Figure 5. New firms – Percentage change from BaU (supply elasticity for new designs = 0.15)

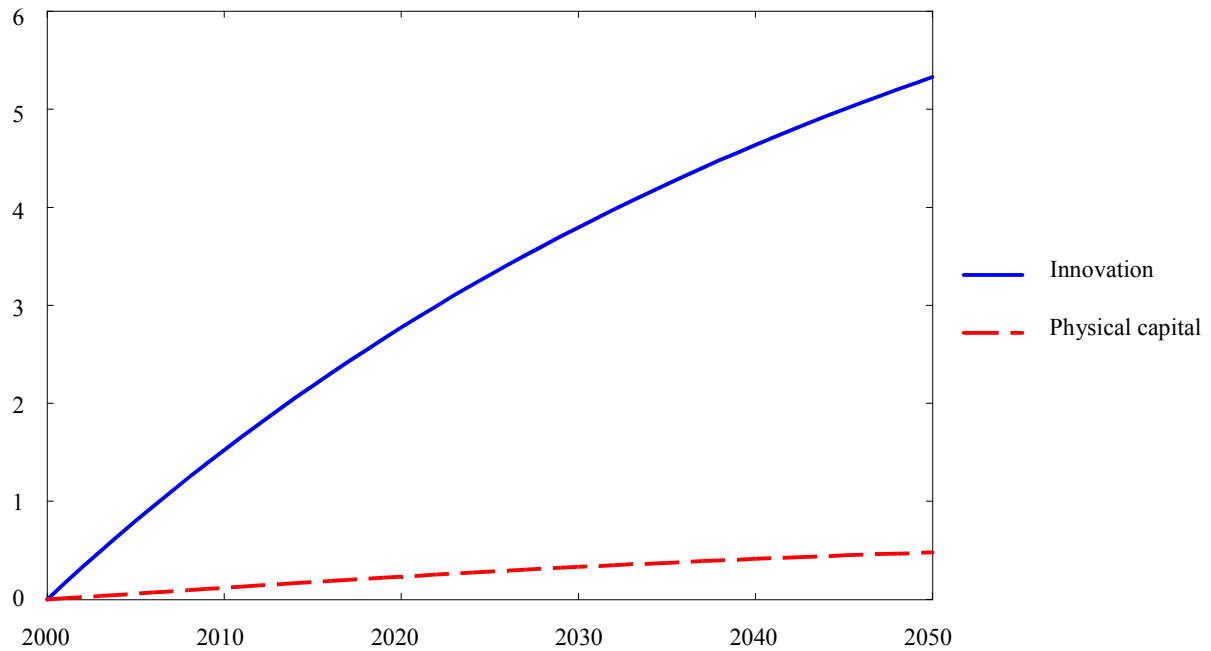


Figure 6. Existing firms – Percentage change from BaU (supply elasticity for new designs = 0.15)

