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INTERNATIONAL SPILLOVERS, PRODUCTIVITY GROWTH AND OPENNESS IN THAILAND: AN INTERTEMPORAL GENERAL EQUILIBRIUM ANALYSIS

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Abstract

Thailand has experienced economic growth well above world averages for about 40 years. It is a challenge to understand the sources of this high growth path, and in particular why growth has not slowed down with assumed decreasing returns to capital. We develop an intertemporal general equilbrium model separating between agriculture and industry, and with open capital market and endogenous productivity growth to analyze the underlying adjustment mechanisms. Foreign technology spillover embodied in trade is assumed to be the driving force of the productivity growth, consistent with econometric evidence. The high growth experience is understood as a transition path with interaction between productivity growth, openness and capital investment. Counterfactual analysis shows how protection may have had serious detrimental effect on growth rate due to productivity and investment slowdown. The role of relative prices in constraining growth is investigated, inspired by the Acemoglu-Ventura hypothesis of growth slowdown due to terms of trade effect. In our setting, low elasticity between domestic and exports goods in supply leads to large relative price shifts for domestic goods, but promotes investment and growth during transition.

JEL classification: O4, O5; key words: intertemporal growth modelling, endogenous productivity growth, foreign technology spillover, trade and growth, Thailand

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1. Introduction

Income differences across countries cannot be understood only as a result of different production factors. The empirical evidence that capital stocks per worker explain limited part of the income differences among nations now seems widely accepted. The attention therefore is turned to productivity and technology, and productivity differences between countries are substantial, as documented by Hall and Jones (1999). Acemoglu and Ventura (2001) find that the world income distribution is remarkably stable over time. It follows that differences in income levels are permanent, while differences in growth rates are mostly transitory. The understanding is that countries grow more rapidly the further they are below their steady states (Mankiw et al., 1992). A corollary to this is that miracle growth countries cannot produce miracles over long periods. Growth rates will decline again to world normals.

The present paper addresses the growth process of Thailand in this perspective. After all the theoretical growth modeling and the cross-country growth regressions, we suggest to go back to the country level to understand the growth dynamics. The focus is on endogenous productivity growth in transition towards long run balanced growth. Thailand has had remarkable economic growth of about 6-7% and well above world averages for 40-50 years, in transformation from a ‘rice economy’ to industrialization. Interestingly, this follows an earlier deindustrialization from domestically oriented rural industries to specialization in rice exports (the period 1870-1940). The more recent transformation has involved industrialization with labor-intensive manufacturing exports.

The literature on endogenous productivity growth points to the role of research and development and innovation. But these key sources of productivity growth do not seem to be of great relevance for Thailand. Resource input to research and development is concentrated to the most developed countries of the North. Innovation is the result of R&D and certainly requires advanced skills, again not characterizing the local growth process. Human capital development and skill accumulation are important ingredients in recent models of endogenous growth. While education and skill levels have been rising in

Thailand, the low-tech labor-intensive industries in the country do not indicate that this is a major growth factor. Our analysis addresses learning by doing, technology adoption and foreign technology spillover as sources of productivity growth. Based on recent econometric evidence for Thailand, our understanding is that productivity growth has been related to the increased openness of the economy with the associated spillover of knowledge, incentives to improved organizational capital and disciplining of the work process. Greenaway et al. (2002) supplies broader evidence about openness and growth.

Thailand's growth experience is analyzed as an interaction between endogenous productivity growth and capital accumulation with increased openness of the economy. This mechanism explains the extended transition growth above long run balanced growth rates. To investigate the transition path and the role of openness, we have developed an intertemporal, general equilibrium model with productivity dynamics that allows counterfactual analysis. The model calibration is based on the combination of a social accounting matrix, econometric evidence, and stylized facts of the Thailand economy. The model describes an economy with macroeconomic stability, full employment of resources, and flexible allocation of resources between sectors according to profitability. The assumptions are heroic, but then Thailand has enjoyed an impressive growth record with the ability of holding macroeconomic balance and reasonably full utilization of resources. The long run steady state equilibrium only serves as a reference point in our study.

The model is calibrated to reproduce a transition growth rate above the assumed steady state growth rate of 5.5%. The establishment of the transition path explains the prolonged growth path of the economy above world normals. Based on the transition path, the model enables us to study counterfactual developments of the economy. Since the role of openness is assumed essential for the productivity growth, we look at a counterfactual of reduced openness. The growth scenario and the macroeconomic balances would have been less favorable according to the adjustment mechanisms of the model.

The delayed return to world growth rates has been an issue in the theoretical debate, and Acemoglu and Ventura (2001) turn the attention to terms of trade effects. While terms of trade are assumed fixed at world market levels in the model, the adjustment of relative prices between domestic and export goods are important for the growth process. This is investigated in an experiment studying various elasticities of substitution between domestic goods and exports, and it is shown that the country can take more benefit of international trade and the capital market when exports are more independent of the domestic market.

Section 2 puts the analysis in the context of the recent literature on productivity growth, and discusses empirical studies of the growth process in Thailand. Section 3 outlines the productivity dynamics, and section 4 describes the full intertemporal model. Calibration is explained in section 5. The high growth transition path with growth above the long run rate is presented in section 6, and the sources of growth are decomposed. Sections 7 offers counterfactual analysis of openness, while section 8 investigates the relative price mechanisms of growth slowdown towards steady state. Concluding remarks are collected in section 9.

2. Productivity and foreign spillovers

The shift of focus from long-run growth rate to income level implies that the choice of technology is at the forefront. The standard neoclassical Solow and Hecksher-Ohlin-Samuelson models assume common technology and therefore concentrate on factor allocation. Investment levels explain differences in per capita income. In the context of development and growth, it seems to us more productive to assume capital mobility and limited international mobility of technology, as argued by Eaton and Kortum (1999). Adoption of technologies from abroad then is the main determinant of technological progress in countries like Thailand.

Our approach is inspired by the learning by doing literature innovated by Arrow (1962) and in particular the emphasis on technology diffusion associated with international trade suggested by Krugman (1979). In a separation between North and South, he assumes innovation in the North and imitation in the South. This is an early contribution with a long-run equilibrium where North and South have the same growth rate, but permanent income differences. The South can improve its position by raising the ability to imitate. Technological differences are expected to be very important without trade since the South hardly can produce the 'new' goods innovated in the North. Modern authoritative treatments of foreign spillovers are Grossman and Helpman (1992) and Aghion and Howitt (1998).

Two competing understandings of the technological differences have emerged in the literature. The first assumes that technologies developed in the North are less appropriate for the South. Atkinson and Stiglitz (1969) in an early contribution argue that the productivity of the technology is related to the capital-labor ratio. When technological progress is 'localised' to the capital-labor ratios of the North, the South will have a technological disadvantage because of less capital intensity. The dynamics of 'localised learning by doing' is recently worked out by Basu and Weil (1998). Another reason for the difficulty in adopting advanced technology is the low level of human capital, as suggested by Nelson and Phelps (1966). They assume exogenous growth of a best practice technology frontier. The ability to catch up with the frontier depends on the human capital level of the country. Low human capital makes the country poor because it cannot take advantage of modern technology. Given the formulation of the gap, low human capital may be compensated by large technology gap. Acemoglu and Zilibotti (2001) develop the understanding of the skill requirement, and they explain the low productivity in the South by a skill-bias in the technology.

The alternative view assumes barriers to technology adoption, as suggested by Parente and Prescott (1994). They look at technology as a production factor, and investment in technology explains productivity. Again the improvement in productivity depends on the distance to the exogenous world technology frontier, and investment is needed to benefit from the world technology. The costs of investment come out as a key determinant of productivity, and the authors see these costs mainly as the result of distortions created by policy. Eaton and Kortum (2001) investigate empirically equipment prices as such a barrier, based on the observation that equipment prices fall systematically with development. Our formulation of foreign spillover for Thailand can be understood as a barrier that is influenced by international trade. As mentioned in the introduction, our interpretation is that openness influences technological knowledge, organizational capital and organizational discipline.

Technology spillovers as discussed above represent the dominating explanation for convergence of economic growth across countries. All countries can take benefit of the growth of the world technology frontier, albeit in different degrees and speeds. The controversy over the Asian miracles has focused on the fact that growth rates have not declined quickly even when they have a high investment level. They are expected to run fast down the decreasing return to capital. We agree with Ventura (1997) that Asian economies probably have been able to meet the diminishing returns through increased international trade. He emphasizes the shift from labor-intensive to capital-intensive industry along with the capital accumulation. This mechanism seems less relevant for Thailand, since manufacturing and exports have not had a clear shift towards capital-intensive products. Howitt (2000) argues that convergence to a common growth rate with different productivity levels is consistent with a Schumpeterian model. While this certainly may be important generally, the underlying assumption of endogenous innovations in R&D-firms is not characterizing the industrial structure in Thailand. The Acemoglu and Ventura (2001) hypothesis that relative price effects explain the return to world growth rates is discussed and analyzed below.

Growth accounting analyses of Thailand have been abundant as part of the controversy over the broader East Asian experience. Young (1994) argues in an influential article that the Asian economies have rapid growth due to rapid capital accumulation and not as a result of extraordinary productivity growth. Klenow and Rodriguez (1997) challenge the conclusions of Young, and their analysis gives more room for productivity effects. We emphasize the interaction between endogenous productivity growth and capital accumulation.

In his emphasis of factor accumulation to explain East Asian growth, even Young (1994) reached the conclusion that Thailand has had TFP growth of approximately 2 percent (1979-85). In a re-analysis for a longer time-period, 1960-94, Collins and Bosworth (1996) also estimate TFP growth of close to 2 percent. Tinakorn and Sussangkarn (1998) report from 10 studies where TFP growth estimates vary from 0.5 to 2.7 percent, that is from 7 to 40 percent of the overall growth rate (of 7 percent). Their own analysis of new GDP data for 1980-95 find TFP growth of about 2 percent, although 40 percent of this can be explained by improved labor quality. In this analysis land is included as production factor and labor input is adjusted for changes in education, age and sex composition. TFP growth then is down to 1.3 percent.

Given the TFP measure of productivity growth, the roles of within-sector learning by doing, spillovers from other sectors, and international spillovers can be estimated econometrically. In an econometric analysis for 22 developed countries Coe and Helpman (1995) show the importance of linking a country's productivity gains to foreign R&D capital and trade volumes. The more open an economy is, the better it can take advantage of international R&D capital. Edwards (1998) investigate the effect of 9 alternative measures of openness on TFP growth in a dataset of 93 countries. He concludes that more open economies indeed have experienced faster productivity growth.

Tinakorn and Sussangkarn (1998) relate annual aggregate TFP growth in Thailand 1981-95 to the capital stock, the openness of the economy, and the sectoral allocation of employment. The effect of the variables can be interpreted as learning by doing driven by domestic factors and foreign spillover, and they all are of statistical significance. Uruta and Yokota (1994) find that TFP growth in manufacturing increases with trade liberalization (measured by effective rates of protection). Rattsø and Stokke (2002) apply the method and the disaggregated data of Tinakorn and Sussangkarn (1998) for agriculture and industry to investigate more closely the dynamics of productivity and foreign spillover. Constant factor shares, calculated as average over the period 1980-95, are assumed in the calculation of sectoral TFP, and growth of total cultivated land is included for agriculture. The channel of foreign spillover is measured by total imports and total foreign trade. Possible endogeneity is handled with lags. The relationships are estimated with fairly general dynamic formulations using error-correction models. The estimates consistently show a clear short run relationship between measures of foreign trade and sectoral productivities. Interestingly, the qualitative and quantitative effect of foreign trade on productivity is similar in both agriculture and industry. Both sectors seem to enjoy foreign spillover and are equally able to take benefit of them.

The quantitative effects are of economic importance. In their preferred equation, Rattsø and Stokke (2002) conclude that the short run elasticities of productivity with respect to foreign trade are 0.36 in agriculture and 0.55 in industry. When foreign trade goes up by 10 percent, sectoral productivities go up by 4-5 percent. Since growth of foreign trade has been higher than the overall economic growth in Thailand, this seems to be the major determinant of productivity growth. The results hold in a broader econometric model where domestic spillovers and within sector learning by doing are included as independent variables. Although there are econometric challenges with endogeneity of openness in these studies, they offer an interesting starting point for generalizations about the technological progress, and back up the productivity formulation assumed in the model below.

3. Productivity dynamics

Our framework to analyze productivity growth looks at the balance between agricultural and industrial growth, with industry covering the 'rest of the economy'. In this section we show the endogenous productivity relationships that are integrated in the full intertemporal general equilibrium model. The sectoral production functions are defined as:

$$X_M = \tilde{A}_M L_M^a K_M^{1-a} \tag{1}$$

$$X_A = \tilde{A}_A L_A^{b_1} LD^{b_2} K_A^{1-b_1-b_2} \tag{2}$$

where $\tilde{A}_i$ is total factor productivity (TFP) for sector *i*. Subscript *M* is for industry and *A* for agriculture. *L* indicates labor, *LD* land, and *K* capital, and $0 < \alpha < 1$, $0 < \beta_1, \beta_2, \beta_1+\beta_2 < 1$. Labor and capital are mobile across sectors, while land is a sector specific input only for agriculture. Moreover, the supply of the land is fixed in the economy over time. For this reason, together with different capital intensity across the two sectors, we need differential growth rate for TFP across sectors in order to have a balanced growth path. We introduce labor-augmenting technical progress A, which is equal in the two sectors, and land augmenting technical progress A_D, to have:

$$\tilde{A}_M = A^{\alpha} \qquad (3)$$
$$\tilde{A}_A = A^{\beta_1} A_D^{\beta_2} \qquad (4)$$

(3) – (4)

It follows that the growth path of the sectoral TFP is as follows:

$$\frac{\dot{\tilde{A}}_M}{\tilde{A}_M} = \alpha \frac{\dot{A}}{A}$$
$$\frac{\dot{\tilde{A}}_A}{\tilde{A}_A} = \beta_1 \frac{\dot{A}}{A} + \beta_2 \frac{\dot{A}_D}{A_D}$$

(5) – (6)

In the case of Thailand, and similar for many developing countries, agriculture is more labor intensive than that of industry. Thus, it is reasonable to assume that $\alpha < \beta_1$. For this reason, the balanced growth path requires that TFP in agriculture grow more rapidly than that in industry.

The literature on sources of productivity growth discussed above suggests that growth through learning by doing and international spillover is encouraged by the linkage between domestic economy and international markets. The econometric analyses referred to document the importance of this relationship for Thailand, both for agriculture and industry. The standard formulation was suggested already by Nelson and Phelps (1966) and assumes technology gap from present productivity level to best practice. In our context we can assume a catch-up to a world technology frontier W and a speed of closing the gap ϕ dependent on a measure of international trade T:

$$\frac{\dot{A}_t}{A_t} = \phi(T_t)\left(\frac{W_t - A_t}{A_t}\right) \qquad (7)$$

With this formulation, the TFP growth is faster the further the economy is away from the world frontier. Nelson and Phelps assume that human capital is the main determinant of the speed of catch-up, but the dynamic properties are similar and depend on the growth of the frontier. Since this Thailand study concentrates on transition growth, we can avoid the complications of the long run dynamics of learning by doing outlined by Young (1991). Accordingly we can assume that Thailand is well below the world technology frontier for the whole period under study. Labor-augmenting and land-augmenting productivities are simply related to total trade (T):

$$\begin{aligned} A &= f(T) \\ A_D &= g(T) \end{aligned} \qquad (8)-(9)$$

where f and g represent general functional forms. With this setup, the sectoral productivity growth rates are consistent with a steady state growth path:

$$\begin{aligned} \frac{\dot{X}_M}{X_M} &= \alpha\varepsilon_A \frac{\dot{T}}{T} + \alpha \frac{\dot{L}_M}{L_M} + (1-\alpha)\frac{\dot{K}_M}{K_M} = g + n \\ \frac{\dot{X}_A}{X_A} &= \beta_1\varepsilon_A \frac{\dot{T}}{T} + \beta_2\varepsilon_D \frac{\dot{T}}{T} + \beta_1 \frac{\dot{L}_A}{L_A} + (1-\beta_1-\beta_2)\frac{\dot{K}_A}{K_A} = g + n \end{aligned} \qquad (10)-(11)$$

The steady state is defined by the exogenous long-term growth rate for the country's overall technical progress g, and the exogenous labor supply growth rate n. The elasticities, ε_A and ε_D, reflect the effects of trade growth for labor-augmenting and land-augmenting technical progress, respectively.

4. The intertemporal general equilibrium model

We model a small open economy that faces a perfect international capital market. The economy is small in the sense that its capital accumulation and growth do not influence the world interest rate, which we therefore assume to be exogenously given. A small open economy model with exogenous interest rate and no imperfections in the capital market gives immediate adjustment of the capital stock to its steady state level if the model is calibrated to an out of steady state (SS) path. The economy will take advantage of the foreign borrowing opportunity to finance the investments to fully exploit the profit opportunities along the steady state. Consistent with this, the consumption path is unaffected. Introducing adjustment costs in investment is a common way of creating interesting dynamics in such a model. Moreover, as shown by Diao et al. (1998), imperfect substitution between domestic and foreign goods through an Armington composite system would also constrain the speed of return to SS. We choose both approaches in this paper. The alternative would be to look into constraints and risks at international capital markets, which represents a future challenge for this kind of models.

To have a consistent basis of growth analysis, we assume intertemporal saving and investment decisions. The representative household is forward looking with rational expectations. The household allocates consumption and saving to maximize an intertemporal utility function, while capital is allocated based on the intertemporal profit maximization. Since investment can be financed through foreign borrowing, the decisions about savings and investment can be separated. Domestic savings and investments do not have to be equal in every period, but a long-run restriction on foreign debt exists. We apply the model setup of Diao et al. (1998) as a benchmark with endogenous determination of sectoral total factor productivities as the main extension. In addition, the adjustment costs are introduced for investment, and land is specified as an input in agricultural production. Full documentation of the intertemporal general equilibrium model is given in a separate appendix.

4.1 The household and consumption/saving

The representative household allocates income to consumption and savings to maximize its intertemporal utility. There is no independent government sector so public tax revenues (import tariffs and sales taxes) are transferred to the household lump sum. In addition, it receives income through the primary factors, while interest payments on its foreign debt are subtracted. We consider an infinite horizon model, and utility is maximized subject to an intertemporal budget constraint, which says that discounted value of total consumption cannot exceed discounted value of total income. With the usual restrictions, we have the well-known Euler equation for optimal intertemporal allocation of consumption:

$$\frac{E_{t+1}}{E_t} = \frac{1+r}{1+\rho} \tag{12}$$

where r is the exogenous world interest rate, ρ is the positive rate of time preference, and E_t is total consumption spending in period t. The growth of consumption spending depends on the relationship between the interest rate and the time preference rate. Higher interest rate and lower time preference rate motivate more savings and thereby higher consumption spending growth.

4.2 Investment and capital stock

The aggregate capital stock is managed by an independent investor who decides on investment and passes net profits to the household. Adjustment costs of the investment, φ_t, are assumed to be a convex function of investment (I) over existing capital stock (K):

$$\varphi_t = a \cdot P_{m,t} \cdot \frac{I_t^{\,2}}{K_t} \tag{13}$$

where a is constant and $P_{m,t}$ composite price of the industrial good.

The investor chooses an investment path so as to maximize the present value of future profits over an infinite horizon, subject to the capital accumulation constraint. First order conditions for labor and land equilibrate marginal return and unit cost of the representative factor. Differentiating with respect to I gives:

$$q_t = PI_t + 2 \cdot P_{m,t} \cdot a \cdot \frac{I_t}{K_t} \tag{14}$$

where PI_t is the unit cost of the investment that eventually forms the capital equipment. This relationship says that investment will equilibrate the marginal cost of investment, which is given on the right hand side, and the shadow price of capital, q_t. Differentiating with respect to K_t gives us the well-known no-arbitrage condition:

$$rq_{t-1} = Rk_t + P_{m,t} \cdot a \cdot \left(\frac{I_t}{K_t} \right)^2 - d \cdot q_t + \dot{q}_t$$

which states that marginal return to capital has to equal the interest payments on a perfectly substitutable asset of size q_{t-1}. The first term on right hand side of the equation (Rk_t) is the derivative of capital in the production function, while the second term is the derivative of capital in the function for investment adjustment cost. The marginal return to capital also has to be adjusted by the depreciation (δ) and capital gain ($\dot{q}$).

4.3 Foreign sector and foreign debt

We assume imperfect substitution between domestic and foreign goods, so the model operates with two composite goods, one agricultural and one industrial. Imports are endogenously determined through the Armington functions, while exports are determined through the Constant Elasticity of Transformation (CET) functions. As discussed earlier, this is a way to create transitional dynamics in a small open economy model facing a perfect international capital market and exogenous interest rate given from the world market.

If domestic investments exceed domestic savings, the gap is financed through foreign borrowing. Increase in the foreign capital inflows (i.e., trade deficits) in the current period, together with interest payments on existing debt, augments foreign debt in the next period.

4.4 Equilibrium

In each period (intra-temporal equilibrium) the following conditions must be fulfilled; (1) in each sector domestic demand plus export demand equal total output; (2) factor demand equals factor supply; (3) investments equal domestic savings and foreign borrowing.

The steady state equilibrium requires that capital stock and foreign debt ($DEBT$) grow at a constant rate given by $g + n$:

$$I_T = (d + g + n)K_T \tag{15}$$

$$FSAV_T = (g + n - r)DEBT_T \tag{16}$$

where $FSAV$ is the trade deficit. Finally, the shadow price for the capital becomes constant, as does the marginal return to capital:

$$Rk_T - a \cdot P_{m,T}\left(\frac{I_T}{K_T}\right)^2 = (r + d)q_T \tag{17}$$

The subscript T represents the time periods of the steady state.

5. Model implementation and calibration

The model analysis assumes that Thailand's recent growth experience can be understood as high transition growth on its way to long run steady state growth. The intertemporal general equilibrium model is calibrated to a steady-state equilibrium with a balanced growth path. The choice of steady state growth rate for Thailand's GDP serves as a long run constant, but is not important for the understanding of growth mechanisms below. The model is calibrated to a steady state growth rate of 5.5 percent, assuming labor force growth of 2.8 percent and overall technological progress of 2.7 percent. With the balanced growth assumption, all other endogenous variables, such as capital stock and investment, savings and consumption, sectoral outputs and trade, have to grow at this rate along the steady state path.

Parameters in the numerical model are calibrated from the data. The parameters in the production, demand, and trade functions are set according to the method adopted in most static computable general equilibrium models and are based on a social accounting matrix (SAM). The Thailand's SAM for 1989 is developed by Jemio and Jansen (1993) with six production sectors and four economic agents. For this study, we aggregated the SAM into two production sectors (agriculture and industry, including services) and one representative household. The calibrated share parameters in the Cobb-Douglas production function for labor are 0.42 in the industry and 0.58 in agriculture, indicating that agriculture is more labor intensive. Based on the SAM, the domestic savings rate was about 31 percent, and investment accounted for 39 percent of GDP. Domestic savings financed 80 percent of investment while the other 20 percent was financed through foreign capital inflows. The agricultural value-added accounted for 16.5 percent of GDP, while the industry represented the remaining of 83.5 percent. The indirect taxes in agriculture and industry equaled 0.05 and 17 percent of GDP, respectively. The elasticity of substitution in both the Armington and CET functions are assumed to be 3. These elasticities represent substitution possibilities between domestic and foreign goods (Armington), and between sales to domestic markets versus export markets (CET).

We choose domestic interest rate to be 0.09 based on IMF (2000), and depreciation rate 0.10. Then, with the steady state assumption, most parameters regarding to the intertemporal feature of the model can also be calibrated from the same SAM. The initial capital stock and investment are derived from the steady state condition in (15), using data from the SAM. Equations (14) and (17), together with the depreciation rate, are used to calibrate the shadow price of capital, q, the coefficient, a, in the capital adjustment cost function, and the marginal return to capital (0.14). The initial level of foreign debt is calibrated from (16) given the data about trade deficit/surplus included the SAM, together with the choices of the interest rate and long-run growth rate. The time preference rate is calculated from the Euler equation (12) and is 0.035.

The levels of TFP by sector and the relationships between TFP and foreign trade in (8-9) are also calibrated from the SAM and based on the econometric evidence discussed in section 2. The foreign spillover effect of trade is assumed proportional to both labor-augmenting and land-augmenting technological progress, implying an elasticity of 1. This is consistent with the econometric estimate of industrial TFP to total trade of about 0.4-0.5 when we take into account the labor share of industry of 0.42. To be consistent with the steady state, foreign trade is scaled by labor supply for labor-augmenting technical progress. The calibration of the agricultural TFP path is harder, since the model assumes fixed land while the TFP calculations are based on increased land input. In practice the area of cultivated land in Thailand is about constant over time, but the share of the land irrigated has increased from 22 to 33 percent during the period of study. It seems to us that a large part of the agricultural productivity growth results from increased irrigation. Because of the fixed land assumption of the model, the elasticity of technological spillover from foreign trade in the agricultural TFP function (0.78) is adjusted up compared to the econometrically estimated elasticity of about 0.3-0.4. Details about the calibrated parameters and initial values of the intertemporal variables are in Appendix Table 1.

6. Transition growth path

Thailand's growth experience is a puzzle as seen from standard growth theory. How can the country stay above a realistic long run steady state growth rate and above world growth normals for such an extended period? The actual growth rate has been about 6-7 percent until the Asian crisis, as compared to the assumed steady state growth of 5.5 percent. The background of the growth process is discussed in a broad literature (see the nice overview of Jansen, 2001 with references). Our approach is more narrow to investigate the mechanisms of transition growth related to recent growth theory.

The first step of the analysis is to derive a transition that is close to the real growth path between 1960-90 for Thailand and the transitional path eventually converges to the steady state path with a 5.5 percent long-run growth rate. Establishing this transition is a challenge in an intertemporal model with assumptions of small open economy and open capital markets, because it is known that in its most flexible form, the capital stocks will immediately adjust to steady state by foreign borrowing. Two modifications mentioned above, i.e., the assumptions of imperfect substitution between domestic and foreign goods and the convex adjustment costs in investment help the model to have a transition path for a prolonged period. The first assumption introduces two 'home' goods such that prices for sector's commodities become endogenously, while the second assumption holds back the adjustment speed in investment and capital accumulation and hence constrains the convergence to the steady state. The endogenous productivity growth related to the openness of the economy also contributes to continued high transition growth.

We calibrate to the transition path by bringing down the initial capital stock in 1960 to about 10 percent of its level in 1989, such that the initial level of real GDP is close to the data in that year. Levels of labor supply and sectoral TFP are also reduced by the constant annual growth rates of n and g, respectively. The balance between the state variables capital stock and foreign debt is important for the out of steady state position and foreign debt is adjusted to reproduce the initial year. Figure 1 shows the path of real GDP for both data and the calibration. It can be seen that the transition path of our model matches with the data quite well during the period under study and started to depart after 1990. The reason is that the transition path calibrated has to converge to the steady state with a 5.5 percent long-run growth rate, while Thailand enjoyed the high growth rate (above 8 percent) after 1990 until the Asian crisis (1997).

Figure 1 about here

Once the economy is brought down below the steady state path, the growth rate of investment rises above $g+n$ (but converges to $g+n$ eventually). With increase in investment, together with growth in TFP, we observe that the growth rates of GDP and capital stock are higher along the transition during the first 20 years (Figures 2a-b). The growth rates are about 8-9 percent for capital stock and 7-8 percent for GDP during the early years and reduce to around 7 percent later. While the major underlying mechanism is the standard convergence effect of the higher marginal productivity of capital, the endogenous productivity response to increased trade also contributes to the rapid growth rate in GDP and capital accumulation.

Figure 2a-b about here

The macroeconomics of the transition path shows the role of the open capital market assumed. With a smoothing consumption path, foreign capital inflows become important for the growth process. 50 – 75 percent of investment has to be financed by foreign inflows during the early years along the transition, up from 19 percent along the steady state path. This is shown in Figure 3 and is described as intertemporal trade. As the investment expansion needs more imports, the early inflows have to be financed by future export earnings. Of course, with the new production capacity and higher productivity, more exports are generated in the future. The handling of this intertemporal trade balance is the key to development success or failure. The model presented here and the Thailand application obviously tells the success version.

Figure 3 about here

In addition to the rising capital intensity along the transition, the productivity is further improved. Our productivity formulation assumes learning by doing generated by spillovers from abroad. Change in the openness of the economy is assumed to affect productivity levels in agriculture and industry. Along the steady state path, TFP in agriculture grows by 2.6 percent per year, while TFP in industry grows by 1.1 percent. While the sectoral difference in TFP growth rate is supported by the growth accounting evidence, it is mainly explained by the role of fixed land and the higher labor intensity of agriculture.

Increase in imports driven by investment demand along the transition implies increase in total trade, which causes more foreign technology spillover compared to the steady state. As investment goods are mainly industrial goods, the immediate effect along the transition is the rise in the imports of industrial goods. Share of imports over total absorption for the industrial sector is up 25%, while the import share for the agricultural goods is not much affected. Growth in the total exports is immediately slowing down compared to the steady state, but then it becomes much stronger. Thus, the growth in both imports and exports has consequences for productivity improvement in both sectors. The TFP growth rate rises to 3 – 3.4 percent in agriculture (from 2.6 percent as steady state level) and 1.3 – 1.5 percent in industry (from its 1.1 percent steady state level) in the first 20 years. These high productivity growth rates certainly contribute to the rapid growth in the economy, and also stimulate investment by increasing the profitability of investment. Productivity and investment effects actually go hand in hand in explaining the high growth path along the transition.

Figure 4a-b about here

Decomposition of the transitional growth process is shown in Figures 4a-b, based on the sectoral growth equations presented in (10-11). The decomposition shows clearly how endogenous improvement in TFP along transition generates more capital accumulation. When the economy is brought down to the 1960s' level, the accumulation of capital is the immediate dominating growth factor, and investment explains 70 percent of the growth in industry and 30 percent in agriculture. As seen from the diagrams, productivity growth quickly picks up, driven by the imports first and then by the exports. In the medium-run along the transition, improvement in productivity represents about 50 percent of growth in agriculture (as land productivity growth has to be high) and 20 percent of growth in industry. Capital accumulation is always dominating factor for growth in industry (about 60 percent in the medium run). Since the labor supply grows exogenously at 2.8 percent, both sectors enjoy expansion of the employment, which contributes upon 20 percent of growth in both sectors.

7. Counterfactual analysis -- reduced openness

The Thai economy has been outward oriented, and most analysts have attributed the growth performance to trade liberalization and the access to foreign capital and technology (Karunaratne, 1999 and Kochhar et al. 1996 in an IMF study). To further evaluate the importance of openness in growth, a counterfactual experiment is conducted by exogenously imposing an additional 10 percent of tariffs in industry. While others have investigated trade liberalization in a static general equilibrium framework for Thailand (notable Karunaratne, 1999), we can offer an analysis of the dynamic consequences. Given the structure of the economy, the direct effect of the high tariff barrier is to raise the cost of the investments as imports of capital goods become more expensive. Depressed investments, together with the reduction in imports of industrial goods, feed back to affect the productivity. The consequent drop in productivity growth strengthens the negative effect on investment profitability. Thus, the dynamic effects of protection are further augmented.

The purpose of protection is to reduce imports from protected sector. However, as growth expectation is lowered, the foreign financing of investment also declines. While the foreign financing inflows accounted for 60 – 75 percent of investment during 1960s in the calibrated model for Thailand, the protectionism reduces this to below 55 percent (Figure 4). In total, the investment share in GDP immediate declines to 38 percent from 50 percent in the first transition exercise, and the consequences for the growth of the capital stock as well as of GDP are significant. As shown in Figure 2, the growth of the capital stock and GDP drops to below the 5.5 percent steady state rate (from 9 – 7 percent in the calibrated transition) for the first 10 years. The lowered growth rate over the transition creates a large income gap. Measured by the level of real GDP, the income gap due to protection is about 25 percent of the real GDP in the 19th year and widens to 40 percent in the 40th year (Figure 5). This result tells us that that even though the growth rates in both scenarios – calibrated transition and the protection – converge to the same steady sate growth rate (of 5.5 percent), i.e., even though the rapid growth is transitory, the loss in the national income due to protection is permanent. Thus, if we treat these two cases as two countries, Thailand, the more opened economy, and one of the other developing countries which is less open, the protection adopted by the other country will produce a permanent income gap between this country and Thailand, unless the country changes its policy, opening up to the world and have more rapid growth.

Figure 5 about here

While the protectionism in industry raises the cost of investment, it primarily hits the growth in industry itself in the dynamic framework. The contribution of industry to GDP growth falls down about 3 percentage points in the short-run and 1.5 percentage points in the medium-run along the transition. This result contrasts with a typical static analysis, in which the protected sector – here industry – should benefit from the protection.

The protectionism also has a detrimental effect on the productivity. As discussed above, imports of industrial goods fall with the lowered investment level. Exports are not much affected immediately, but the growth is reduced. The growth in exports and imports drops from 7 percent to 5.5 percent, which causes the spillovers to contract and growth in TFP to slow down (Figure 6). While in the transitional exercise the trade share is about 55 percent of GDP, the trade share falls to below 50 percent with the protectionism, resulting in the TFP growth slowdown. Interestingly, the productivity of agriculture is hit harder in the early years than that in industrial sector. This is shown in Figure 6a where TFP in agriculture is below that in industry with protection until the 15th year. Agriculture is more strongly affected in this simulation, since land productivity responds more to spillover than labor. Figure 6b implies that the TFP growth driven by the high investment and high imports in the transitional exercise is missed out in this experiment with the protection. Along the new path, the TFP growth rate in industry is about 1.1 percent, while TFP growth in agriculture is far below 3 percent.

Figure 6 about here

The dynamic productivity and growth effects of the protection should be understood as an interaction between investment and learning by doing from the spillovers. The immediate reduction of investment with more expensive imports of the capital goods affects the structure of the economy so that it is less adaptable to foreign technology spillover. The consequent drop in productivity growth strengthens the negative effect on investment profitability. The model offers a lesson about how the dynamics of productivity and investment may accumulate to serious income level effects over time.

8. Growth decline and domestic-export goods substitution

The growth process involves changes in relative prices reflecting the structure of the economy. Acemoglu and Ventura (2001) argue that terms of trade adjustment explain the decline and convergence of growth rates by high growth economies. Specialization in varieties forces the countries to run down demand curves at the world market. In our setup, the varieties are restricted, the world market demand is perfectly elastic, and the terms of trade are fixed. But the imperfect substitution between domestic and foreign goods allows an investigation of relative prices driven domestically. Agricultural and industrial goods can be treated as intermediates in consumption and investment, and the intermediates are produced by labor, capital and land. The hierarchy separates between domestic goods delivered to the international market, domestic goods applied domestically, and foreign goods imported. The Armington functions determine the variety composition of domestic goods and imports, while the CET functions determine exports versus domestic use. Our focus here is on the analysis of domestic versus export goods in supply.

The starting point is early transition growth with low capital stocks and demand pressure related to high investment. What relative price effects play out and how are they associated with different growth scenarios?

The numerical experiment compares low (1.5) and high (6.0) elasticity of substitution between domestic and export goods, as compared to the calibrated benchmark of 3.0. In the case of low elasticity, domestic and export goods are like different goods for the producer. The domestic demand pressure under transition and the following increase in the relative price of domestic goods have little effect for export production. The export supply is not much responsive to the domestic market, and the relative price shift will be large. When exports are kept up during the transition, the dynamic foreign constraint allows for large investment, high foreign savings, and more trade. When exports are independent of the domestic market, the country can take more benefit of trade and capital markets.

Figure 7 presents the alternative growth paths for GDP dependent on the three values of the elasticity of substitution. During transition growth, the high elasticity growth is well below and the low-elasticity growth is well above the reference path. The quantitative effects are quite large and represent about 1 percentage point growth rate on each side. The same holds for the capital stock. As can be seen, the high investment alternative has a higher speed of return to the steady state. The scenario looks like the small open economy, but here this follows when the substitution possibilities between domestic and export goods are small in supply.

Figure 7 about here

The standard understanding is that the small open economy with perfect capital market implies high growth transition quickly returning to the steady state. When the capital market is closed, the global market is no constraint on prolonged high growth because the economy can expand along perfectly elastic export demand curves. Acemoglu and Ventura (2001) show how price-response at the world market under specialization leads to decline in growth rates. The Thailand model offers insight about another mechanism related to relative prices and exports adjustment. When there is high substitution between domestic and export goods supply, similar to the small open economy, resources are easily shifted out of exports to satisfy domestic demand under transition. The worsening of the exports growth path will reduce early transition growth.

Figure 8a-b about here

The endogenous productivity growth of the model implies that the differences in early transition have permanent effects. Figures 8a and 8b show that industrial imports are permanently higher with low elasticity and consequently that the TFP level in industry will stay higher. The economy takes long run advantage of being able to shelter exports production from domestic competition.

9. Concluding remarks

Thailand has experienced economic growth well above world averages for about 40 years. It is a challenge to understand the sources of this high growth path, and in particular why growth has not slowed down with assumed decreasing returns to capital. We develop an intertemporal general equilbrium model separating between agriculture and industry, and with open capital market and endogenous productivity growth to analyze the underlying adjustment mechanisms. Foreign technology spillover embodied in trade is assumed to be the driving force of the productivity growth, consistent with available econometric evidence. The high growth experience is understood as a transition path with interaction between productivity growth, openness and capital investment. Counterfactual analysis shows how protection may have had serious detrimental effect on growth rate due to productivity and investment slowdown. The role of relative prices in constraining growth is investigated, inspired by the Acemoglu-Ventura hypothesis of growth slowdown due to terms of trade effect. In our setting, low elasticity between domestic and exports goods in supply leads to large relative price shifts for domestic goods, but promotes investment and growth during transition.

Our analysis contributes to the literature evaluating short and long run effects of trade liberalization. Diao et al. (1999) show how trade liberalization may give short run welfare gain, but long run welfare loss in Japan. Their explanation is that liberalization gives domestic industrial expansion, but then crowds out foreign spillovers over time. Compared to Japan, Thailand's trade protection has concentrated more on industry than agriculture. Rausch (1997) find that trade liberalization in Chile gives short run growth decline, but long run welfare gain. In his model, trade liberalization gives specialization in traded goods with productivity growth, but immediate contraction in the non-traded sector. In this Thailand model industry and growth is hurt by protectionism in the short and the long run, over time the effect is driven by the relationship between openness and productivity growth. It is a challenge to investigate more closely the dynamics of the productivity relations assumed here and factors affecting technology adoption and learning from abroad, in particular related to skill formation.

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References

Acemoglu, D. and J. Ventura (2001), The world income distribution, NBER Working Paper 8083.

Acemoglu, D. and F. Zilibotti (2001), Productivity differences, Quarterly Journal of Economics 116, 2, 563-606.

Aghion, P. and P. Howitt (1998), Endogenous Growth Theory, Cambridge, Ma: MIT Press.

Atkinson A. and J. Stiglitz (1969), A new view of technological change, Economic Journal 79, 573-578.

Arrow, K.J. (1962), The economic implications of learning by doing, Review of Economic Studies 29, 155-173.

Basu, S. and D. Weil (1998), Appropriate technology and growth, Quarterly Journal of Economics 113, 4, 1025-1054.

Coe, D. and E. Helpman (1995), International R&D spillovers, European Economic Review 39, 859-887.

Collins, S. and B. Bosworth (1996), Economic growth in East Asia: Accumulation versus assimilation, Brookings Papers on Economic Activity 2, 135-203.

Diao, X., E. Yeldan and T. Roe (1998), A simple dynamic applied general equilibrium model of a small open economy: Transitional dynamics and trade policy, Journal of Economic Development 23, 1, 77-101.

Diao, X., T. Roe and E. Yeldan (1999), Strategic policies and growth: An applied model of R&D-driven endogenous growth, Journal of Development Economics 60, 343-380.

Eaton, J. and S. Kortum (1999), International technology diffusion: Theory and measurement, International Economic Review XL, 537-570.

Eaton, J. and S. Kortum (2001), Trade in capital goods, European Economic Review 45, 1195-1235.

Edwards, S. (1998), Openness, productivity and growth: What do we really know? Economic Journal 108, 383-398.

Greenaway, D., W. Morgan and P. Wright (2002), Trade liberalisation and growth in developing countries, Journal of Development Economics 67, 229-244.

Grossman, G. and E. Helpman (1992), Innovation and Growth in the Global Economy, Cambridge, Ma: MIT Press.

Hall, R. and C. Jones (1999), Why do some countries produce so much more output per worker than others?, Quarterly Journal of Economics, 83-116.

Howitt, P. (2000), Endogenous growth and cross-country income differences, American Economic Review 90, 829-846.

IMF (2000), International Financial Statistics Yearbook.

Jansen, K. (2001), Thailand: The making of a miracle? Development and Change 32, 2, 343-370.

Jemio, L. and K. Jansen (1993), External Finance, Growth and Adjustment, Working Paper - Sub-Series on Money, Finance and Development - No. 46, Institute of Social Studies, The Hague, March 1993.

Karunaratne, N. (1999), Trade liberalization in Thailand: A computable equilibrium (CGE) analysis, Journal of Developing Areas, 515-540.

Klenow, P. and A.Rodriguez-Clare (1997), The neoclassical revival in growth economics: Has it gone toofar?, NBER Macroeconomics Annual, 73-103.

Kochar, K. et al. (1996), Thailand: The Road to Sustained Growth, IMF Occasional Paper 146, Washington DC: IMF.

Krugman, P. (1979), A model of innovation, technology transfer, and the world distribution of income, Journal of Political Economy 87, 253-266.

Mankiw, N.G., D. Romer and D. Weil (1992), A contribution to the empirics of economic growth, Quarterly Journal of Economics 107, 2, 407-437.

Nelson, R. and E. Phelps (1966), Investment in humans, technology diffusion and economic growth, American Economic Review, Papers and Proceedings 56, 69-75.

Parente, S. and E. Prescott (1994), Barriers to technology adoption and development, Journal of Political Economy 102, 298-321.

Rattsø, J. and H. Stokke (2002), Learning by doing and domestic and foreign technology spillovers in Thailand: Some empirical evidence, Nordic Journal of Political Economy, forthcoming.

Rauch, J.E. (1997), Balanced and unbalanced growth, Journal of Development Economics 53, 41-66.

Tinakorn, P. and C. Sussangkarn (1998), Total factor productivity growth in Thailand: 1980-95, Macroeconomic Policy Program, Thailand Development Research Institute (TDRI).

Urata, S. and K. Yokota (1994), Trade liberalization and productivity growth in Thailand, The Developing Economies XXXII-4, 444-459.

Ventura, J. (1997), Growth and interdependence, Quarterly Journal of Economics, 57-84.

Young, A. (1991), Learning by doing and the dynamic effects of international trade, Quarterly Journal of Economics 106, 2, 369-406.

Young, A. (1994), Lessons from the East Asian NICs: A contrarian view, European Economic Review 38, 964-73.

Figure 1. Real GDP: data vs. model's transitional path

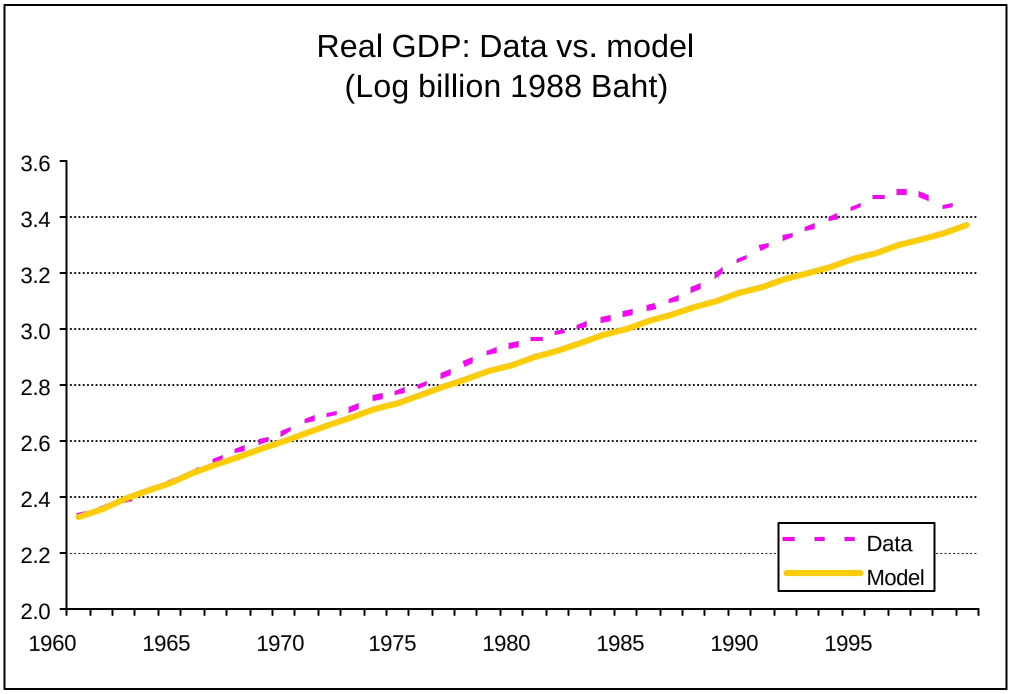
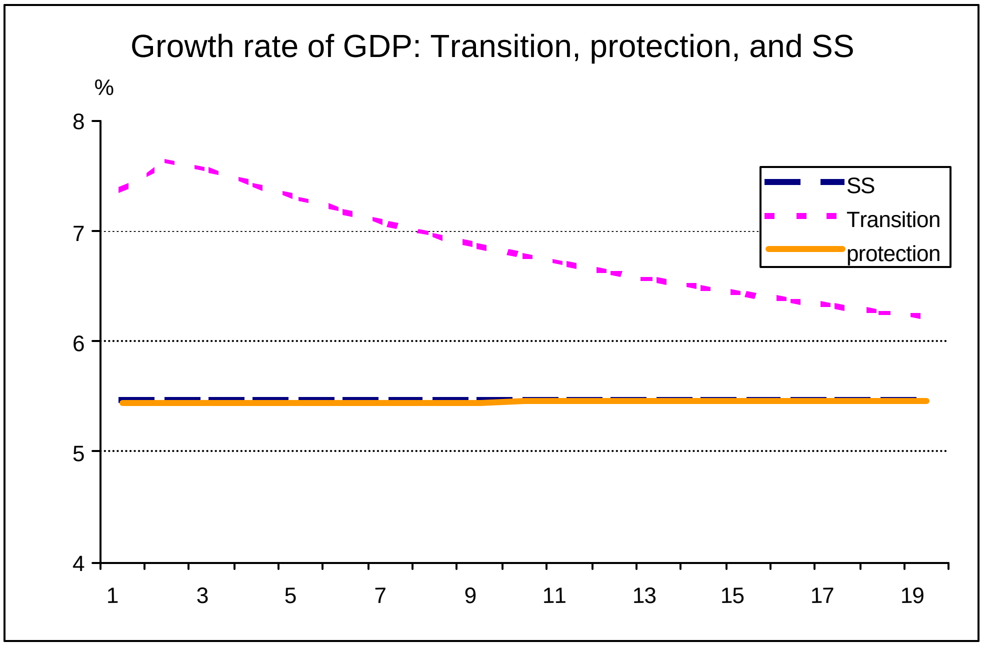


Figure 2a – b Transitional paths for growth rates of GDP and capital stock



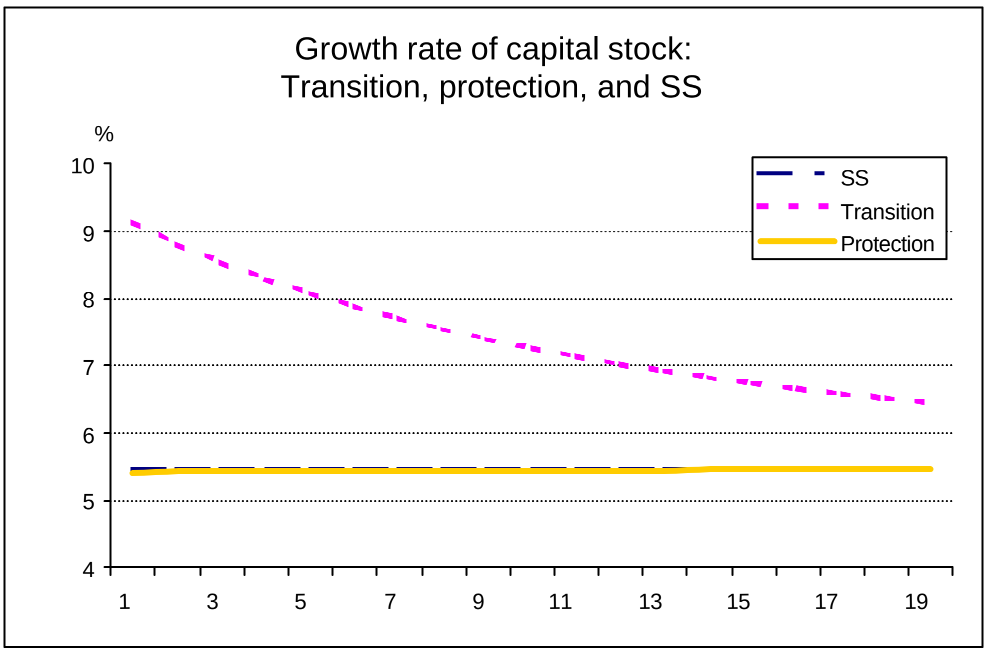


Figure 3. Foreign capital inflows: transition vs. protection

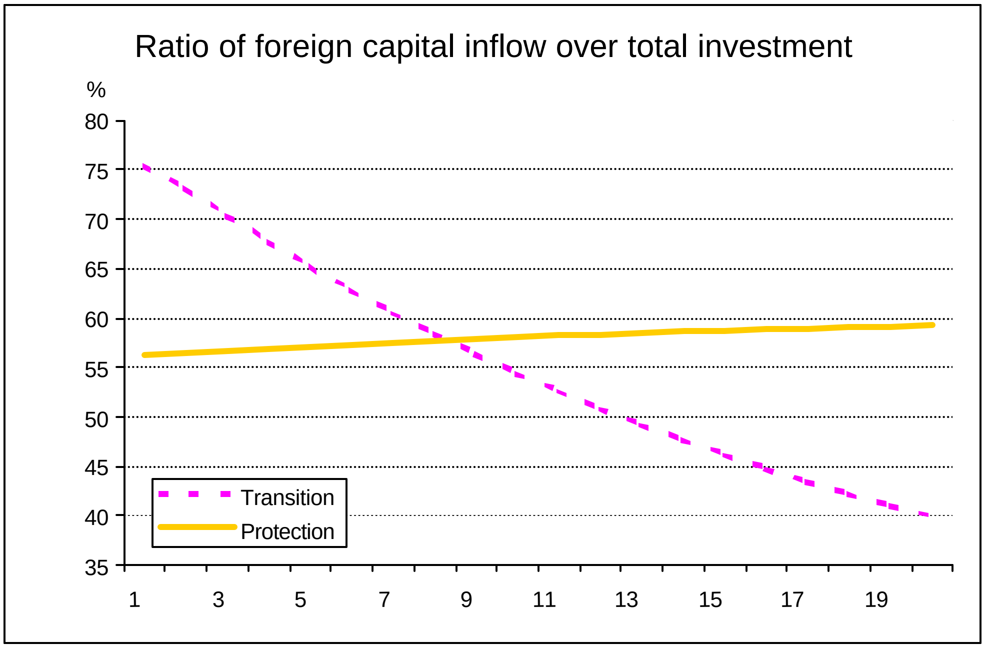
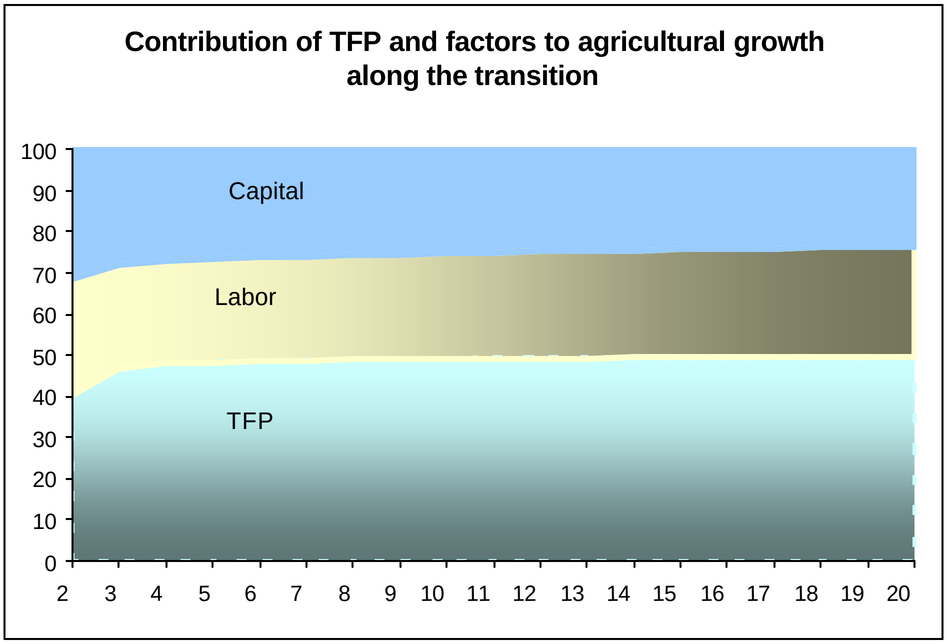


Figure 4a – b. Decomposition of growth along the transition



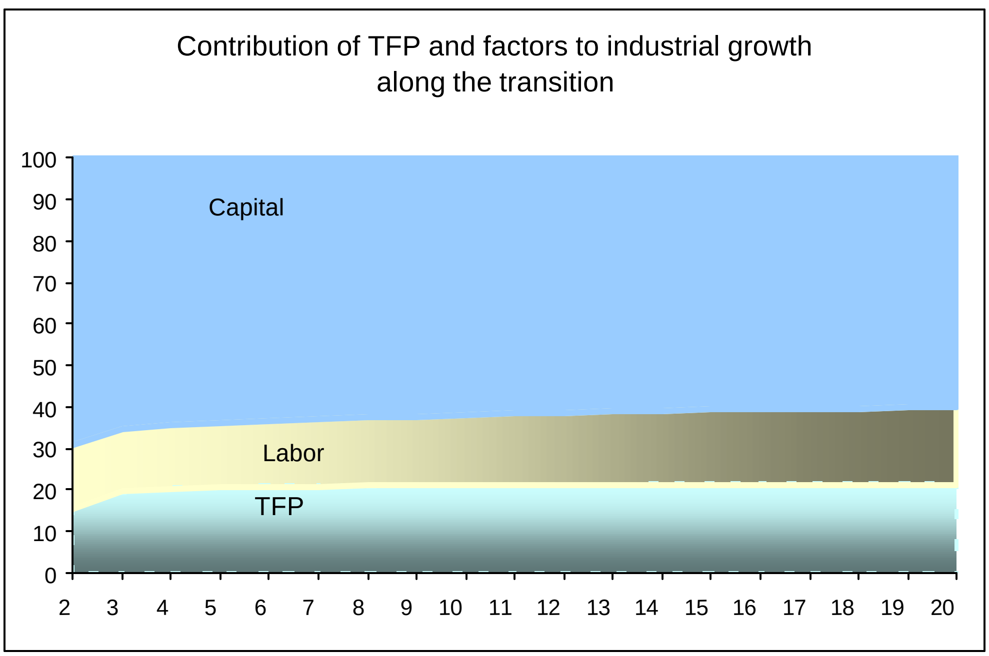


Figure 5. Income gap due to protection

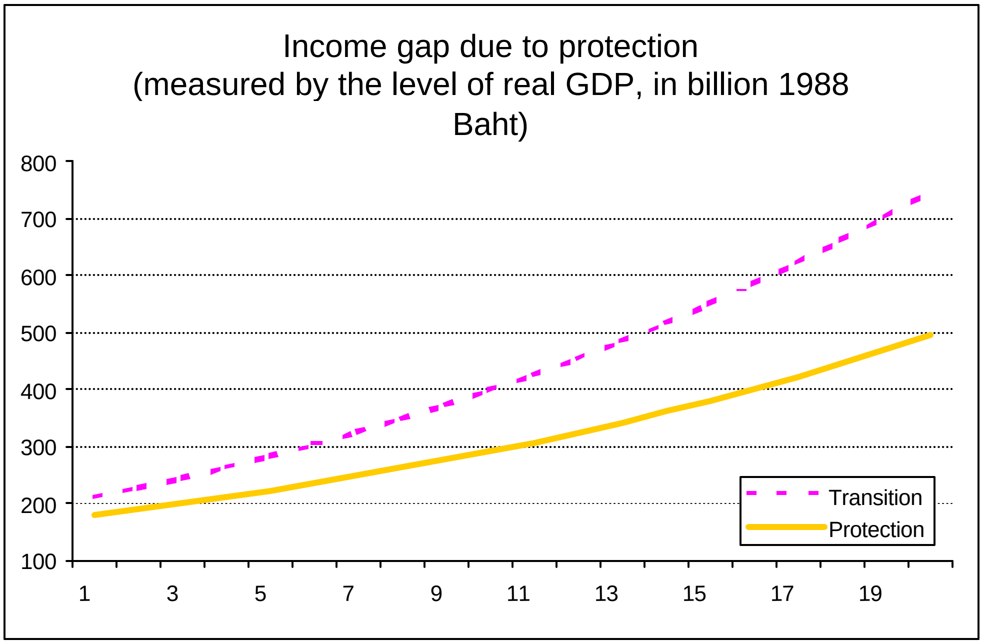
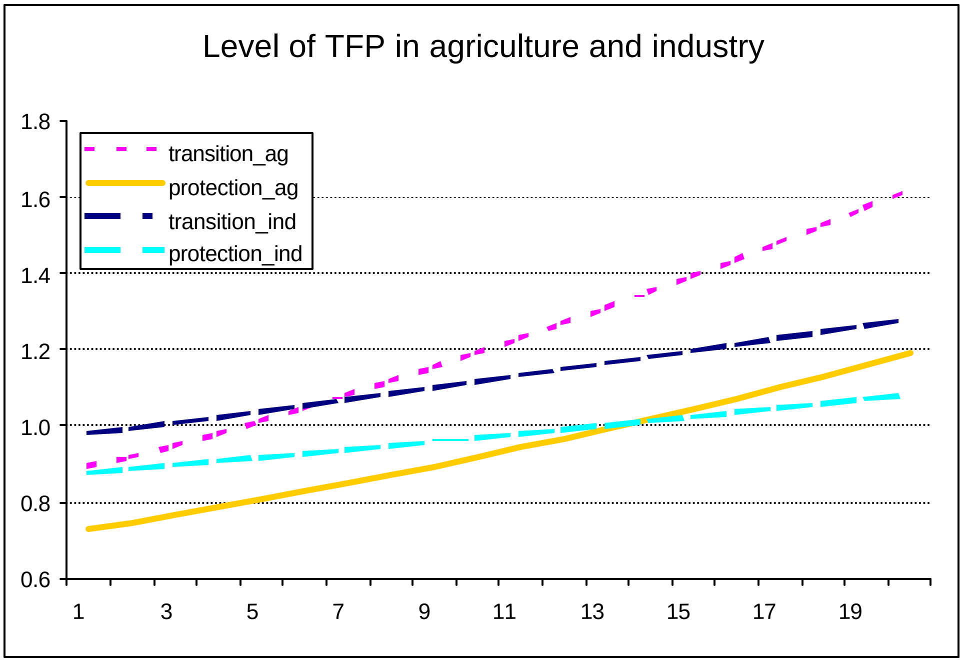


Figure 6a – b. Level and growth rate for sector's TFP: transition and protection



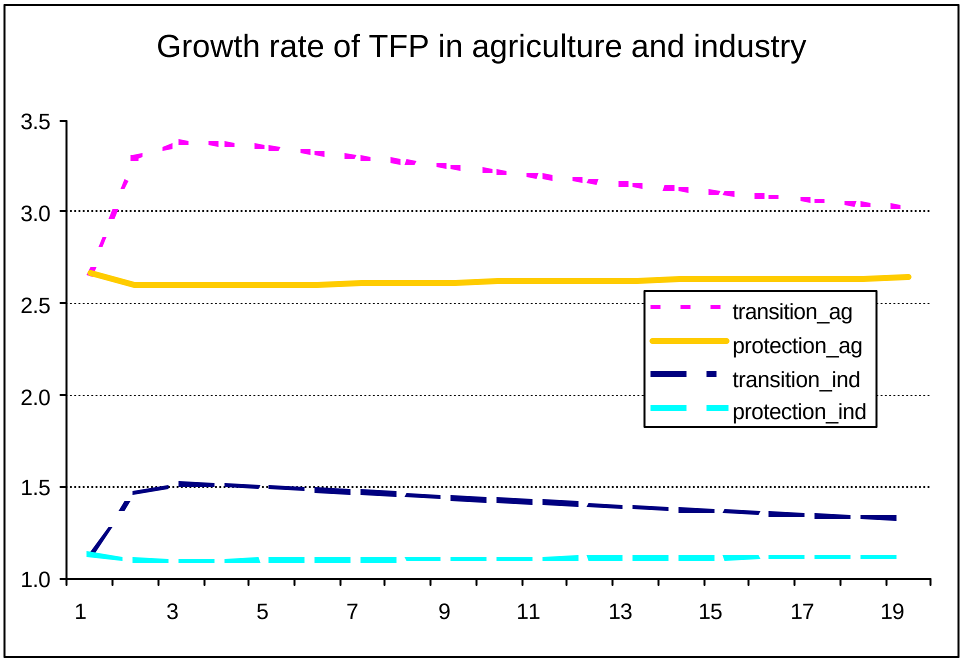


Figure 7. Growth rate of GDP with different domestic-foreign substitution elasticities

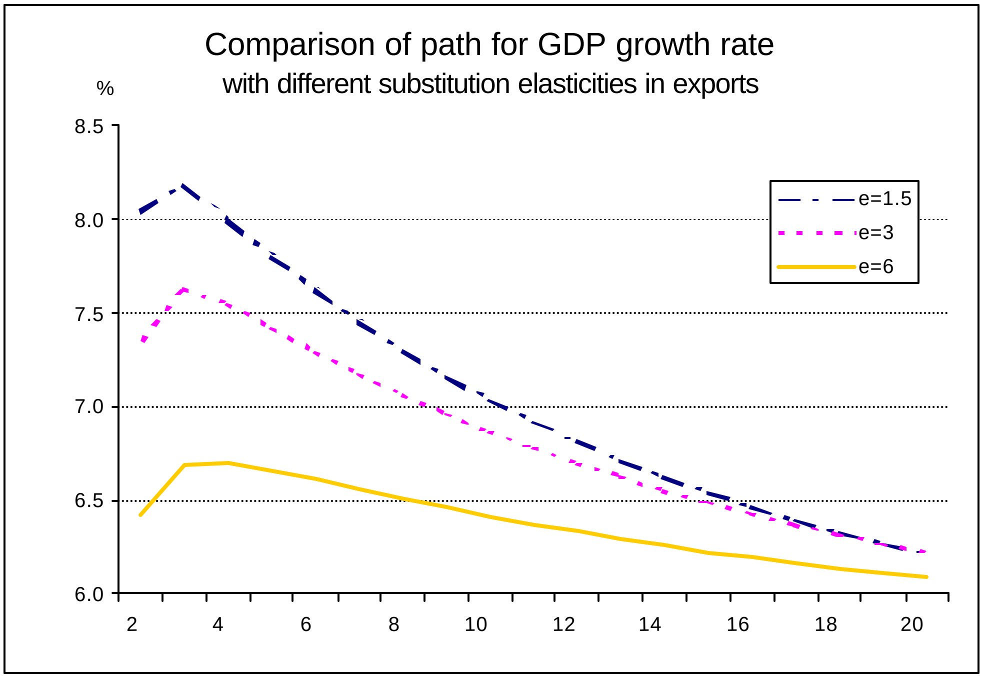
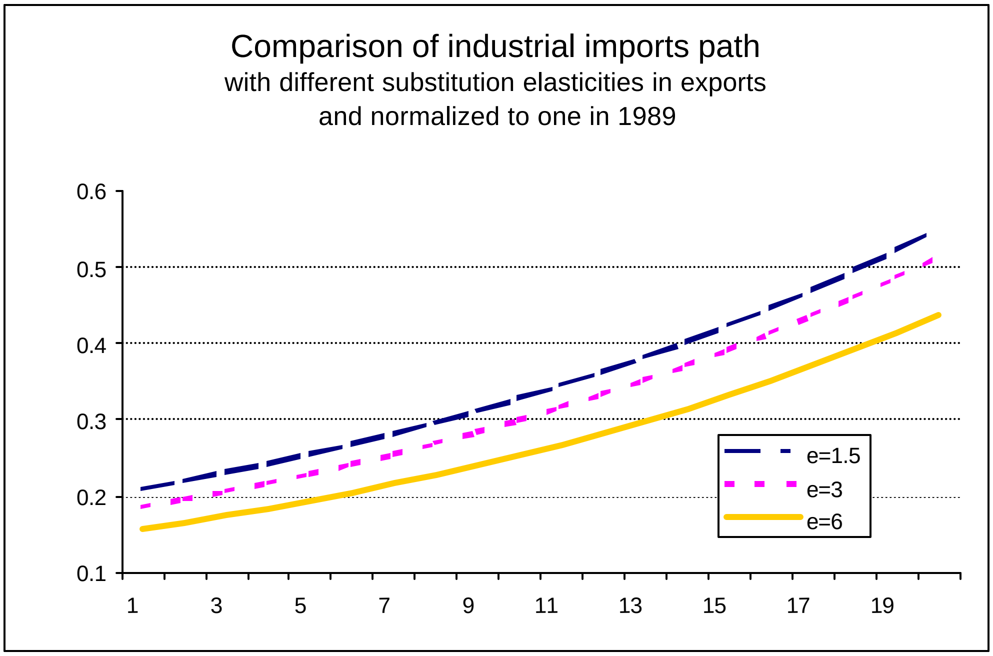
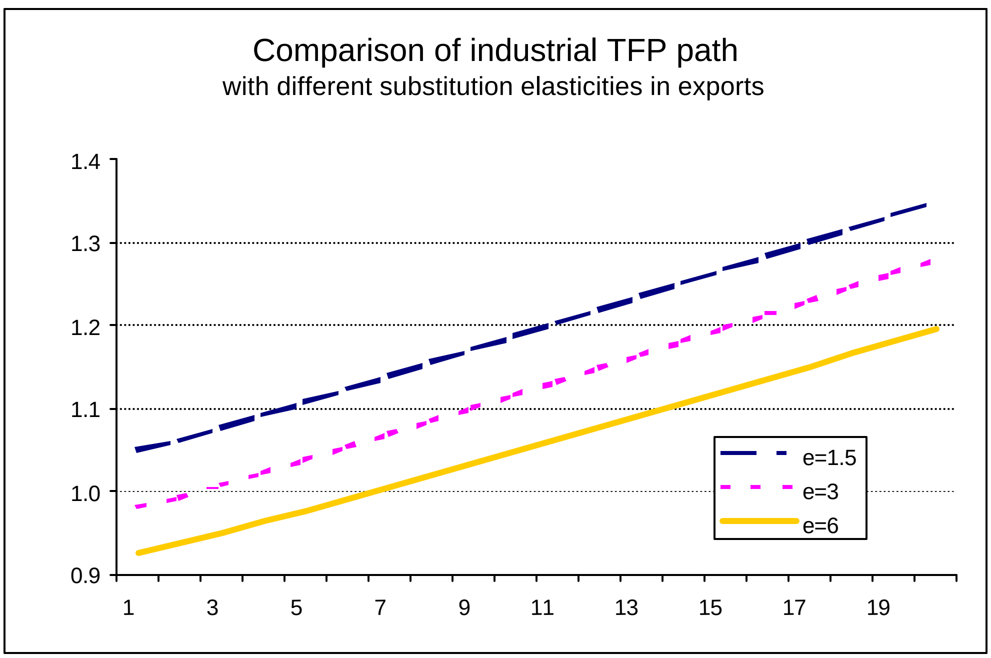


Figure 8 a - b. Comparison of industrial imports and TFP paths
with different domestic-foreign substitution elasticities





Appendix Table:
Values of selected parameters and variables (initial value for endogenous variables)

Definition	Symbol in the model	Value
Parameters		
Share of labor in agriculture	b_1	0.58
Share of labor in industry	a	0.42
Share of capital in agriculture	$1 - b_1 - b_2$	0.22
Share of capital in industry	$1 - a$	0.58
Share of land in agriculture	b_2	0.20
Share of imports in agricultural consumption	ma_a	0.38
Share of imports in industrial consumption	ma_m	0.41
Share of exports in agricultural production	mc_a	0.73
Share of exports in industrial production	mc_m	0.61
Coefficient in adjustment cost	a	2.08
Elasticity in Armington function	s_m	3.00
Elasticity in CET funciton	s_e	3.00
Time preference rate	r	0.033
Depreciate rate	d	0.10
Elasticity of spillover in agriculture		0.78
Elasticity of spillover in industry		0.42
Exogenous variables		
Steady state growth rate	$n+g$	5.5
Growth rate of labor	n	2.8
Growth rate of technology	g	2.7
World interest rate	r	0.09
Endogenous variables		
Marginal returns to capital	$Rk + a \cdot P_m \left(I/K \right)^2$	0.19
Marginal product of capital	Rk	0.14
Derivative of adjustment cost w.r.t capital	$-a \cdot P_m \left(I/K \right)^2$	0.05
Shadow price of capital	q	1.00
Adjustment cost per unit of investment	$a \cdot P_m \; I/K$	0.32
TFP in agriculture	$\tilde{A}_a$	2.49
TFP in industry	$\tilde{A}_m$	1.588
Labor-augmenting technical progress	A	2.993
Land-augmenting technical progress	A_D	4.016

Appendix: The mathematical documentation of the model

A.1. Equations

The following equations are the detailed description of the model. The numerical model is solved by the General Algebraic Modeling System (GAMS).

The consumer's decision

The representative consumer maximizes an intertemporal utility function over time taking into account the current budget constraint for each period:

$$Max \;\; U_1 = \sum_{t=1}^{T} (1+\boldsymbol{r})^{-t} \ln(Q_t) + \ln(Q_T)\frac{(1+\boldsymbol{r})^{1-T}}{\boldsymbol{r}}$$

$$s.t. \;\; \sum_{i}^{T} P_{i,t} \cdot C_{i,t} = Y_t - SAV_t$$

where

U_1 is the value of the intertemporal utility evaluated at time period 1's price.

$$Q_t = cs \cdot \prod_i C_{i,t}^{cles_i}$$

$$Y_t = Wb_t \cdot L_t + Wd_t \cdot LD + Rk_t \cdot K_t + \sum_i tax_i \cdot PX_{i,t} X_{i,t} + \sum_i tm_i \cdot PWM_i \cdot er_t \cdot M_{i,t} - (r-g-n)DEBT_t$$

The first-order condition for the consumer's problem is:

$$\frac{E_{t+1}}{E_t} = \frac{1+r}{1+\boldsymbol{r}}$$

$$E_t = \sum_i P_{i,t} C_{i,t}$$

This equation says that growth in total consumption expenditure depends on the relationship between world market interest rate and consumer time preference rate. The higher interest rate, or the lower time preference rate, the higher consumption growth.

Consumer's demand for each commodity:

$$P_{i,t} C_{i,t} = cles_i \cdot (Y_t - SAV_t)$$

Production decision

The value-added production functions for the two sectors:

$$X_{a,t} = A_t^{b_1} \cdot (A_D)_t^{b_2} \cdot L_{a,t}^{b_1} \cdot LD^{b_2} K_{a,t}^{1-b_1-b_2}$$

$$X_{m,t} = A_t^{\,a} L_{m,t}^{a} K_{m,t}^{1-a}$$

First order conditions are:

$$\mathbf{b}_1 PV_{a,t} X_{a,t} = Wb_t \cdot L_{a,t}$$
$$\mathbf{b}_2 \cdot PV_{a,t} \cdot X_{a,t} = Wd_t \cdot LD$$
$$(1-\mathbf{b}_1-\mathbf{b}_2) PV_{a,t} X_{a,t} = Rk_t \cdot K_{a,t}$$
$$\mathbf{a} \cdot PV_{m,t} X_{m,t} = Wb_t \cdot L_{m,t}$$
$$(1-\mathbf{a}) PV_{m,t} X_{m,t} = Rk_t \cdot K_{m,t}$$

Value-added price for each sector:

$$PV_{i,t} = PX_{i,t}(1-tax_i) - \sum_j P_{j,t} IO_{ji}$$

Intermediate goods are employed according to the fixed coefficient:

$$INT_{i,t} = \sum_j IO_{ij} \cdot X_{j,t}$$

GDP at factor price:

$$GDP_t = \sum_i PV_{i,t} \cdot X_{i,t}$$

Investment decision

Investment decision is made according to intertemporal profit maximization, subject to the accumulation of the capital stock over time:

$$\underset{I,K}{Max} \ \sum_{t=1}^{T} (1+r)^{-t} \left[Rk_t \cdot K_t - Wb_t \cdot L_t - Wd_t \cdot LD - PI_t \cdot I_t - \mathbf{j}_t \right]$$

$$s.t. \ \ K_{t+1} = K_t \cdot (1-\mathbf{d}) + I_t$$

where

$$I_{i,t} = AK \cdot \prod_j IVD_{i,j,t}^{iels_{i,j}}$$

$$\mathbf{j}_t = a \cdot P_{M,t} \cdot \frac{I_t^{\,2}}{K_t}$$

is the adjustment cost in investment.

The first order conditions:

$$q_t = PI_t + 2 \cdot P_{m,t} \cdot a \cdot \frac{I_t}{K_t}$$

$$(1+r) \cdot q_{t-1} = Rk_t + a \cdot P_{M,t} \cdot \left(\frac{I_t}{K_t}\right)^2 + q_t \cdot (1-d)$$

The second equation is the well-known no-arbitrage condition, which states that marginal return to capital has to equal the interest payments on a perfectly substitutable asset of size q_{t-1}.

Investment demand:

$$IVD_{i,t} = {iels_i \cdot PI_t \cdot I_t}/{P_{i,t}}$$

Total investment demand for industrial good has include the adjustment cost:

$$TIVD_{m,t} = {iels_m \cdot PI_t \cdot I_t}/{P_{m,t}} + a \cdot \frac{I_t^{\,2}}{K_t}$$

Exports and Imports

Imports and domestic demand are endogenously determined through an Armington function, and domestic and foreign goods are imperfect substitutes. The demand functions are derived from minimizing current expenditure, subject to the Armington function:

$$Min \quad PM_i \cdot M_{i,t} + PD_{i,t} \cdot D_{i,t}$$

$$s.t. \;\; CC_{i,t} = aa_i [ma_i \cdot D_{i,t}^{-exa} + (1-ma_i) M_{i,t}^{-exa}]^{-1/exa}$$

where

$PM_{i,t} = PWM_i \cdot er_t (1+tm_i)$ is the price of import goods.

The first order conditions:

$$\frac{M_{i,t}}{CC_{i,t}} = aa_i^{\frac{-exa}{exa+1}} \cdot \left(ma_i \frac{P_{i,t}}{PM_{i,t}} \right)^{\frac{1}{exa+1}}$$

$$\frac{D_{i,t}}{CC_{i,t}} = aa_i^{\frac{-exa}{exa+1}} \cdot \left((1 - ma_i) \cdot \frac{P_{i,t}}{PD_{i,t}} \right)^{\frac{1}{exa+1}}$$

where $exa = \frac{1}{s_m} - 1$.

Sales to export market versus domestic market are endogenously determined through a CET function, and domestic and export goods are imperfect substitutes. The supply functions are derived from maximizing current sales income, subject to the CET function:

$$Max \quad PD_{i,t} \cdot D_{i,t} + PE_i \cdot E_{i,t}$$

$$s.t. \quad X_{i,t} = ac_i [mc_i \cdot D_{i,t}^{-exc} + (1 - mc_i) E_{i,t}^{-exc}]^{1/exc}$$

where $PE_{i,t} = PWE_i \cdot er_t$ is the export price.

The first order conditions:

$$\frac{D_{i,t}}{X_{i,t}} = ac_i^{\frac{exc}{1-exc}} \cdot \left((1 - mc_i) \cdot \frac{PX_{i,t}}{PD_{i,t}} \right)^{\frac{1}{1-exc}}$$

$$\frac{E_{i,t}}{X_{i,t}} = ac_i^{\frac{exc}{1-exc}} \cdot \left(mc_i \cdot \frac{PX_{i,t}}{PE_{i,t}} \right)^{\frac{1}{1-exc}}$$

where $exc = \frac{1}{s_e} + 1$.

Foreign borrowing and foreign debt

$$FSAV_t = \sum_i (PWM_i \cdot M_{i,t} - PWE_i \cdot E_{i,t})$$

$$DEBT_{t+1} = DEBT_t \cdot (1 + r) + FSAV_t$$

Foreign debt is accumulated over time from trade deficits and interest payments on outstanding debt.

Factor market equilibrium

$$L_t = \sum_i L_{i,t}$$
$$K_t = \sum_i K_{i,t}$$

From these equations we determine wage rate and marginal product of capital.

Commodity market equilibrium

$$CC_{i,t} = INT_{i,t} + C_{i,t} + TIVD_{i,t}$$

This equation determines the equilibrium price, $P_{i,t}$, for Armington composite goods.

Endogenous productivity

$$A_{t+1} = m \cdot \frac{T_t}{L_t}$$
$$(A_D)_{t+1} = d \cdot T_t$$

where $T_t = \sum_i (E_{i,t} + M_{i,t})$

Foreign spillovers that drive the growth of TFP are assumed to be proportional to the volume of trade.

Terminal conditions (steady state constraints)

The terminal conditions are imposed in the model, such that when the time is beyond T, which is the last period in the model, all endogenous variables have to approach approximately to their steady state situation.

$$FSAV_T = (g + n - r) \cdot DEBT_T$$
$$I_T = (d + g + n) \cdot K_T$$
$$Rk_T - a \cdot P_{M,T} \cdot \left(\frac{I_T}{K_T}\right)^2 = (r + d) \cdot q_T$$

These conditions state that foreign debt and capital stock grow at a constant rate given by $g + n$, and that marginal return to capital becomes constant.

A.2 Glossary

Parameters

b_1	share parameter for labor in agricultural value added function
b_2	share parameter for land in agricultural value added function
a	share parameter for labor in industrial value added function
IO_{ij}	input-output coefficient for commodity i used in sector j
exa	exponent in Armington functions
s_m	elasticity of substitution between imported and domestic goods)
ma_i	share parameter in Armington function for imported good i
aa_i	shift parameter in Armington function for commodity i
exc	exponent in CET functions
s_e	elasticity of substitution between domestic goods and exports
mc_i	share parameter in CET function for export good i
ac_i	shift parameter in CET function for commodity i
$cles_i$	share of consumer's demand for commodity i
cs	shift parameter in total consumption function
AK	shift parameter in total investment function
$iels_i$	share of investment demand for commodity i
a	coefficient in adjustment cost function
r	rate of consumer's time preference
d	capital depreciation rate
m	coefficient in labor augmenting technical progress function
d	coefficient in land augmenting technical progress function

Exogenous variables

LD	land supply
PWM_i	world import price for commodity i
PWE_i	world export price for commodity i
tax_i	sales tax rate for commodity i
tm_i	tariff rate for commodity i
er	nominal exchange rate
r	world interest rate
$g+n$	steady state growth rate
g	exogenous technical progress
n	exogenous labor supply growth rate
L_t	labor supply

Endogenous variables

X_{it}	output of commodity *i*
K_{it}	sector's capital demand
L_{it}	sector's labor demand
D_{it}	good *i* produced and consumed domestically
M_{it}	imports of commodity *i*
CC_{it}	total absorption of composite good *i*
E_{it}	exports of commodity *i*
C_{it}	consumer's demand for good *i*
INT_{it}	intermediate demand for good *i*
IVD_{it}	investment demand for good *i*
$TIVD_{mt}$	total investment demand for industrial good
I_t	investment in quantity
K_t	capital stock
j_t	adjustment costs
Q_t	aggregate consumption
Y_t	consumer's income
SAV_t	consumer's savings
GDP_t	GDP
$FSAV_t$	trade deficit
T_t	total trade
$DEBT_t$	foreign debt
PV_{it}	value added price for commodity *i*
Wb_t	wage rate
Wd_t	land rental rate
Rk_t	rate of return to capital
PX_{it}	producer price for commodity *i*
P_{it}	Armington composite price for commodity *i*
PD_{it}	price for D_i
PM_i	import price for commodity *i*
PE_i	export price for commodity *i*
PI_t	unit cost of investment that builds up capital equipment
q_t	shadow price of capital
A_t	labor augmenting technical progress
$(A_D)_t$	land augmenting technical progress

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