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Learning by exporting and productivity-investment interaction: An intertemporal general equilibrium analysis of the growth process in Thailand*)

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Abstract

While the discussion of Thailand and East Asian growth has been a controversy between capital accumulation and productivity stories, we analyze the general equilibrium interaction between productivity and investment in an intertemporal model. The model builds in endogenous productivity spillover effects influencing profitability and investment and produces long run growth effects of economic policy. To understand the growth process in Thailand, learning by exporting is assumed to be the main vehicle of international spillover and brings further productivity effects to the domestic economy. The dynamic simulations show how high economic growth is prolonged by multisector productivity and investment dynamics and structural shift from agriculture to exportables. The importance of trade liberalization is shown in a counterfactual analysis where protection holds back growth by serving as a barrier to productivity spillover.

JEL classification: O4, O5; key words: intertemporal growth modeling, endogenous productivity growth, learning by exporting, trade and growth, Thailand

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1. Introduction

The sources of the remarkable growth in Thailand and East Asia have been controversial and empirical studies have constructed a horserace between factor accumulation and productivity growth. While the conventional view has recognized high productivity growth associated with openness as part of the explanation (Klenow and Rodriguez, 1997), both empirical (Young, 1994) and theoretical (Baldwin and Seghezza, 1996) studies have argued that capital accumulation has been the main driving force. This debate is hard to understand from a general equilibrium point of view, since both factor accumulation and productivity are endogenous. The conventionally calculated residual underestimates the productivity effect when productivity improvements contribute to higher capital accumulation. Hulten (2001) shows how this induced capital accumulation effect can be calculated. He reports that this measure of the productivity effect accounts for about 50 % of output growth in the East Asian economies studied by Young.

We suggest that the interplay between accumulation and productivity is investigated in an intertemporal general equilibrium framework. The endogenous productivity in new growth theory is combined with investment and structural change during transition from old growth theory (Barro, 1996). In the context of developing countries, productivity growth is driven by catch up and adoption of foreign technology, not by own investments in innovations and human capital. The theoretical understanding of international spillovers can be linked to the old literature on backwardness and development and is called the Veblen-Gerschenkron-effect. It follows that productivity differences between countries are substantial and long-lasting, as shown by Hall and Jones (1999). In our analysis productivity dynamics resulting from foreign spillovers and investment response to productivity generate long run growth rate effects of economic policy.

The ability to take advantage of foreign spillover depends on the industrial structure and the openness of the economy. In the case of Thailand, the open trade regime has allowed for increased foreign trade and foreign investment and has established favorable conditions for productivity growth taking advantage of world markets. Learning by exporting is built in as the main vehicle of international technology spillovers, and they have been embedded in imports of capital goods and intermediates. The export sector has brought further productivity effects to the rest of the economy by substitution for import deliveries to exportables production and investment. In this setting, productivity and accumulation stimulate each other with increased openness of the economy, and the interaction generates an induced capital accumulation effect and affects the long run growth rate.

The analysis is based on an intertemporal, general equilibrium model with four production sectors; exportables, importables, agriculture and nontradables. The multisector productivity dynamics explain how a small open economy can avoid the short transition phenomenon and high growth episodes can last. The model is calibrated to reproduce Thailand’s growth experience, and given the backwardness and catch-up possibilities in the 1960s. The economic structure described represents the conditions for growth established with macroeconomic stability, full employment of resources, open trade regime, and flexible allocation of resources between sectors according to profitability. A counterfactual analysis of protectionist trade policy shows how the catch up and foreign spillover can be held back, resulting in reduced long-run growth rate.

Section 2 puts the analysis in the context of the recent literature on productivity growth, while section 3 discusses empirical studies of the growth process in Thailand. Section 4 outlines the assumed productivity dynamics, and section 5 describes the full intertemporal model. Calibration of the high growth path is presented in section 6, and the sources of growth are decomposed. Section 7 offers counterfactual analysis of openness, while concluding remarks are offered in section 8.

2. Productivity catch up and learning by exporting

The theoretical understanding of international spillovers can be linked to the old literature on backwardness and development and is called the Veblen-Gerschenkron-effect. Economic growth out of backwardness is fundamentally related to technological change.

The backward country can catch up by adopting modern technology and productivity growth is increasing with the size of the gap to the world technology frontier. The view is in conflict with the standard Hecksher-Ohlin-Samuelson models assuming common technology and therefore emphasizing factor allocation. In the context of development and growth, it is more realistic to assume limited international mobility of technology, as argued by Eaton and Kortum (1999), which is consistent with catch-up.

The Veblen-Gerschenkron-effect is first formalized by Nelson and Phelps (1966). They assume exogenous growth of a best practice world technology frontier. The ability to catch up with the frontier depends on the human capital level of the country. Low human capital limits the ability to take advantage of modern technology. Given the formulation of the model, low human capital may be compensated by large technology gap. A modern restatement is offered by Parente and Prescott (1994) introducing the concept barriers to technology adoption. Improvement in productivity is linked to 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 as a barrier resulting from distortions created by policy.

Technology spillovers as discussed above represent an important 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 overcome 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. In our understanding, the multi-sector productivity growth effect of increased openness interacting with capital accumulation explains the high growth path.

It follows that the relationship between foreign trade and capital accumulation must be included in the analysis. Baldwin and Seghezza (1996) emphasize trade-induced investment level as a source of growth. Lee(1995) separates between domestic and foreign capital goods. In his theoretical analysis, capital goods imports promote long-run growth. We exploit this separation both as a distinction between two different capital goods and by having productivity growth associated with imports of capital goods as a spillover. Goh and Oliver (2002) have recently integrated trade in capital goods and learning by doing in a North-South model.

The challenge to productivity growth modeling is to identify the channels of foreign spillover and the transmission process to the rest of the economy. We base our formulation on the documentation of inter-sectoral beneficial externalities of the export sector shown by Feder (1982). His analysis indicates that social marginal productivities are higher in the export sector and that the export sector confers positive effects on the productivity of other sectors in the economy. The learning by exporting clearly involves many aspects of the production process including technological advancement, incentive effects of competition, and transfer of knowledge. Many studies document the empirical significance of imports of machinery and equipment and foreign intermediates. In our analysis, the endogenous expansion of imported capital goods and intermediates are assumed to be driving forces of the productivity growth in exportables. The productivity growth in the rest of the economy results from a combination of foreign spillovers and domestic spillover through sales of intermediates to the export sector. Exporting firms gradually raise their use of intermediates from domestic firms and thereby spread out their learning.

3. Empirical studies of productivity growth in Thailand

Conventional TFP calculations for Thailand tend to identify productivity growth in the order of 2%. Even Young (1994) finds that the country has had TFP growth of approximately 2 percent (1970-85). In a re-analysis for a longer time-period, 1960-94, Collins and Bosworth (1996) 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. When land is included as production factor and labor input is adjusted for changes in education, age and sex composition, TFP growth is down to 1.3 percent.

The sources of the TFP growth have been addressed in an extensive literature with a focus on international spillovers. 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. The conclusion is reinforced in a study of East Asian countries by Frankel et al. (2000) taking into account the endogeneity of foreign trade. The broad empirical background for our analysis is the study of Coe et al. (1997) using a dataset for 77 countries during 1971-90. They conclude that 'a developing country can boost its productivity by importing a larger variety of intermediate products and capital equipment embodying foreign knowledge'. The estimates document a substantial spillover effect of foreign R&D and that spillovers are linked to trade.

The key role of the export sector is supported by recent micro evidence for Thailand supplied by Hallward-Driemeier, Iarossi and Sokoloff (2002). They show how firms interacting with the world market through exports have higher productivity. The article addresses the controversy of causation in the relationship between productivity and exports. Bernard and Jensen (1999) investigate the relationship using US manufacturing data and criticize the wideheld view that exporting raises productivity. They find that trade facilitates growth of high productivity plants and is not increasing productivity growth in each plant. Hallward-Driemeier et al. identify firms that began as exporters and conclude that they have higher productivity years later compared to firms oriented towards the domestic market. We separate out an exportables sector that represents this vehicle of technology adoption.

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 (for the period 1975 – 96). Foreign spillovers are assumed channeled through foreign trade and foreign direct investment (in industry). They observe a strong and fairly robust long-run relationship between openness and productivity in both domestic sectors during a period of increasing trade share of GDP and foreign investment share of investment. The foreign spillover channel explains more than 80% of the TFP growth in agriculture and about 75% of industrial TFP growth during 1975 – 96.

4. Productivity dynamics in the model

To emphasize the role of multi-sector productivity interaction in technology adoption and growth, we disaggregate the economy into four sectors: agriculture, exportables, importables and nontradables. With this sectoral disaggregation, we can investigate sectoral interlinkages and their contribution to economic growth. The export sector is assumed to be 'growth-leading' and provide a key source of foreign spillovers. We further assume that initially the export sector is highly dependent on foreign intermediates and capital goods. Over time, spillovers from the export sector to the rest of the economy result from substitution shift towards domestic intermediates and investment goods. Imported capital is separated from domestic capital in the analysis, which allows for productivity differentiation according to capital use. In this section we show the endogenous productivity relationships that are integrated into the intertemporal general equilibrium model.

The starting point of our formulation is the Nelson-Phelps (1966) model of technology adoption. The adoption is assumed to be driven by intermediate and capital goods linkages to the world market in our case, and the gap to the world frontier is not explicitly included. The dynamics of the productivity functions need to be specified consistent with empirical evidence. We follow the innovative general formulation of Jones (1995) to avoid the scale effect in traditional endogenous growth models. Instead of modeling the productivity growth rate as a function of resources in the R&D sector alone, Jones derives a relationship where the growth rate is affected by the level of productivity, giving constant long run growth rate. We assume 'fishing out' dynamics in productivity growth; the higher level of productivity the harder it is to increase productivity growth. The rate of labor augmenting technical progress *A* for each sector is specified as follows (time subscript is omitted):

$$\frac{\dot{A}_{ex}}{A_{ex}} = d_{ex} \frac{\left(\sum_i M_{it,i,ex} / L \right)^{g_{1,ex}} \left(K_{M,ex} / L \right)^{g_{2,ex}}}{A_{ex}^{1-j_{ex}}} \qquad (1)$$

$$\frac{\dot{A}_j}{A_j} = d_j \frac{\left((D_{it,j,ex} + M_{it,ex,j}) / L \right)^{g_{1,j}} \left(K_{M,j} / L \right)^{g_{2,j}}}{A_j^{1-j_j}}, \text{ for } j = ag,\ im,\ nt. \qquad (2)$$

where $i = ag, ex, im, nt$, representing agriculture, exportables, importables, and nontradables, respectively, $D_{it,i,j}$ and $M_{it,i,j}$ are domestic and imported intermediate good *i* employed by sector *j*, respectively, $K_{M,i}$ imported capital employed in sector *i*, *L* total labor supply in the economy, and $d_i, g_{1,i}, g_{2,i}, j_i$ are constant parameters. Given land supply being constant over time, a land augmenting technical change is assumed in order to have a balanced growth path in the long run.

As the productivity growth rate is endogenously determined at the sectoral level, the economy-wide growth rate must be made consistent with TFP growth rates in the sectors. The following relationship between the economy-wide labor augmenting technical progress and rates of sectoral labor augmenting technical progress is included in the model:

$$g_t = \sum_i s_{i,t} \left(\frac{\dot{A}_i}{A_i} \right)_t, \text{ where } s_{i,t} = \frac{PX_{i,t} X_{i,t}}{GDP_t} \qquad (3)$$

PX_iX_i represents sector value-added and GDP is gross domestic product. With this equation, the economy-wide growth rate is determined endogenously by the productivity dynamics at the sector level and hence the long-run growth rate will change with sectoral TFP growth rates. As the economy-wide growth rate is endogenously determined, an exogenously fixed interest rate, which is consistent with perfect capital market assumption, is no longer suitable for the model. For this reason, the interest rate has to be endogenously linked with the growth rate, and thus, we define the domestic interest rate as a function of world interest adjusted by the degree of openness in the economy:

$$r_t = d \left(\frac{1/2 \cdot \sum_i (E_{i,t} + M_{i,t})}{GDP_t} \right)^e \qquad (4)$$

where d is constant and is calibrated using the long run equilibrium condition between interest rate and economy wide growth rate [given in equation (21) section 5.5], e the elasticity reflecting the effect of increase in openness on the interest rate, and E and M total exports and imports, respectively. Equation (4) implies that when openness (represented by the ratio of trade over GDP) stimulates sectoral TFP growth, the domestic interest rate will simultaneously adjust and will exceed the world market rate to attract more capital inflows.

The rate of the labor augmenting technical progress has to be the same across sectors in the long run and equal to g_T, which implies that $g_{1,i} + g_{2,i} = 1 - j_i$, such that

$$\left(\frac{\dot{A}_i}{A_i} \right)_T = \frac{g_{1,i} + g_{2,i}}{1 - j_i} g_T = g_T \qquad (5)$$

By assuming a negative j_i, higher productivity level lowers productivity growth. Also, we assume that g_2 is greater than g_1, implying relatively larger spillover effect of imported capital than of imported intermediates. While in the long run the rate of the labor augmenting technical progress is the same among the four sectors, because of land employed only in agriculture, and because of the differences in labor intensities, the TFP growth rates are different across sectors even in the long run [defined in (10) – (11) below].

5. The intertemporal general equilibrium model

We model a small open economy where capital accumulation and technological growth do not influence the world prices and interest rate, which are exogenously given. The representative household in the economy allocates consumption and savings to maximize an intertemporal utility function. 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 each 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 growth as the main extension. In addition, we introduce adjustment costs to investment and separate imported capital from domestic capital. The analysis is an extension of Diao et al. (2002) into multisectoral spillover interactions. We describe the most important equations included in the model in the following subsections, while detailed documentation of the intertemporal general equilibrium model is in a separate model appendix.

5.1 Production functions

The sector production functions are defined as:

$$X_i = \tilde{A}_i L_i^{b_{1,i}} K_{D,i}^{b_{2,i}} K_{M,i}^{1-b_{1,i}-b_{2,i}} \qquad i = ex, im, nt \qquad (6)$$

$$X_{ag} = \tilde{A}_{ag} L_{ag}^{a_1} LD^{a_2} K_{D,ag}^{a_3} K_{M,ag}^{1-a_1-a_2-a_3} \qquad (7)$$

where $0 < a_1, a_2, a_3, a_1+a_2+a_3 < 1$, and $0 < b_{1,i}, b_{2,i}, b_{1,i}+b_{2,i} < 1$. $\tilde{A}_i$ represents the level of sector TFP, L_i sector labor demand, LD land, K_D domestic capital, and K_M imported capital. Labor and capital are mobile across sectors. The fixed supply of land is only employed in agriculture. The relationship between sector TFP and labor-augmenting technical progress, A_i, and land augmenting technical progress, A_D , is given as:

$$\tilde{A}_i = A_i^{b_{1,i}}$$
$$\tilde{A}_{ag} = A_{ag}^{a_1} A_D^{a_2} \qquad (8) – (9)$$

It follows that the growth paths of sector TFP are as follows:

$$\frac{\dot{\tilde{A}}_i}{\tilde{A}_i} = b_{1,i} \frac{\dot{A}_i}{A_i}, \qquad i = ex, im, nt$$
$$\frac{\dot{\tilde{A}}_{ag}}{\tilde{A}_{ag}} = a_1 \frac{\dot{A}_{ag}}{A_{ag}} + a_2 \frac{\dot{A}_D}{A_D} \qquad (10) – (11)$$

5.2 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 and the tax revenues in the data (including import tariffs and sales taxes) are transferred to the household lump sum. The household receives income from labor, capital and land, and pays interests on foreign debt. The intertemporal utility function is maximized subject to a 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 allocation of consumption:

$$\left(\frac{Q_{t+1}}{Q_t}\right)^s = \frac{1+r_t}{1+r} \qquad (12)$$

where r_t is the domestic interest rate, r the positive rate of time preference, s the intertemporal elasticity of substitution and Q_t is aggregate consumption in period t. The growth in consumption depends on the relationship between the interest rate and the time preference rate. Higher interest rate or lower time preference rate motivate more savings and thereby higher consumption in the future.

5.3 Investment and capital stock

The aggregate capital stock is managed by an independent investor who chooses an investment path to maximize the present value of future profits over an infinite horizon, subject to the capital accumulation constraint. With a waste due to the adjustment costs in investment, net profits as returns to capital go to the household. The adjustment costs in real terms, ADJ_D and ADJ_M, consume the nontradable good and are specified as:

$$ADJ_{k,t} = a_k \cdot PD_{nt,t} \cdot \frac{I_{k,t}{}^2}{K_{k,t}} \tag{13}$$

where a_k is constant and PD_{nt} price of the nontradable good, $I_{k,t}$ investment in real term, $K_{k,t}$ stock of capital at t.

Differentiating the intertemporal profit function of the investor with respect to $I_{i,t}$ gives:

$$q_{k,t} = PI_{k,t} + 2 \cdot PD_{nt,t} \cdot a_k \cdot \frac{I_{k,t}}{K_{k,t}} \tag{14}$$

where $PI_{k,t}$ is the unit cost of the investment net adjustment costs. This relationship says that the investor equilibrates the marginal cost of investment, which is given on the right hand side of (14), and the shadow price of capital, $q_{k,t}$. Differentiating the same function with respect to $K_{k,t}$ gives us the well-known no-arbitrage condition:

$$r_t \cdot q_{k,t-1} = Rk_{k,t} + a_k \cdot PD_{nt,t} \cdot \left(\frac{I_{k,t}}{K_{k,t}} \right)^2 - d_k \cdot q_{k,t} + \dot{q}_{k,t} \tag{15}$$

which states that marginal return to capital has to equal the interest payments on a perfectly substitutable asset of size $q_{k,t-1}$. The first term on right hand side of (15), $Rk_{k,t}$, is the capital (domestic and imported) rental rate, while the second term is the derivative of capital in the adjustment cost function (13). The marginal return to capital also has to be adjusted by the depreciation rate, d_k, and capital gain or loss, $\dot{q}_k$.

5.4 Foreign sector and foreign debt

Imports in the model are distinguished by different uses, i.e., imports for final consumption, intermediate inputs, or investment demand. There is imperfect substitution between domestic and imported consumption and intermediate goods (through the Armington functions), while domestic and foreign investment goods are separated. In addition, goods producing for the domestic markets versus for exports are imperfect substitutable (the CET functions). If domestic investment exceeds domestic savings, the gap is financed through foreign borrowing. Increase in 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.

5.5 Long-run equilibrium

The long-run equilibrium requires that capital stocks and foreign debt (*DEBT*) grow at a constant rate given by g_T+n, where n is growth rate for labor supply. This implies that the following relationships between investment and capital, and between trade deficits/surplus and foreign debt have to hold:

$$I_{D,T} = (d_D + g_T + n)K_{D,T} \tag{16}$$

$$I_{M,T} = (d_M + g_T + n)K_{M,T} \tag{17}$$

$$FSAV_T = (g_T + n - r_T)DEBT_T \tag{18}$$

where *FSAV* is the trade deficits (surplus if negative). With positive foreign debt in the long run, the country has to run trade surplus as $r_T > g_T+n$ from (12). Finally, in the long run, the shadow price for capital becomes constant, so does the marginal return to capital:

$$Rk_{D,T} - a_D \cdot PD_{nt,T}\left(\frac{I_{D,T}}{K_{D,T}}\right)^2 = (r_T + d_D)q_{D,T} \tag{19}$$

$$Rk_{M,T} - a_M \cdot PD_{nt,T}\left(\frac{I_{M,T}}{K_{M,T}}\right)^2 = (r_T + d_M)q_{M,T} \tag{20}$$

To have consumption growth consistent with the economy wide growth rate, the following relationship between interest rate and growth rate has to hold in the long run [derived from the Euler equation in (12)]:

$$\left(1+g_T+n\right)^s = \frac{1+r_T}{1+r} \tag{21}$$

6. Calibration of Thailand's growth path

The intertemporal model is calibrated to reproduce Thailand's growth experience 1968-98 driven by endogenous investment and productivity. The assumed long-run equilibrium growth rate is 5.5% (2.75% technological progress rate and 2.75% labor growth). The parameters that support this long-run equilibrium are mainly based on a 1998 social accounting matrix (SAM), as documented in the appendix. The original SAM includes 180 production sectors, which are aggregated into four sectors according to trade-production ratio (except for agriculture which is defined by production characteristics). The calibration assumes that 1998 represents long run balanced growth, i.e. the savings-investment can support a sustainable growth path, the structure of the economy is stable, and the trade surplus with interest payments balances the projected development of foreign debt. The SAM is consistent with such an equilibrium, except for that the investment level has been adjusted up (depressed by the Asian crisis).

Starting from 1998, we calibrate backward a growth path that is close to the actual real GDP growth for the previous three decades. The initial level (1968) of capital stocks is reduced to about 10 percent of the level in 1998, such that the initial level of real GDP in the model is close to the actual in 1968. The level of labor supply is reduced by the constant annual growth rate, n (2.75%), and foreign debt in the initial year is reduced to about 20% of the level in 1998. Initial levels of sector TFP are scaled down. The scaling back serves as an exogenous shock that takes the economy outside the equilibrium long run path, and driven by the endogenous mechanisms in the model it converges to the long run growth path.

This design of the growth reproduction assumes that Thailand in the 1960s experienced new growth opportunities. They can be understood as the result of reforms combining trade liberalization, export promotion and investment support. In the model this is observed as high marginal return to investment in the beginning of the growth period studied, with consequent high investment growth and capital accumulation. Increased investments in the early periods are mainly financed by foreign capital inflows and imply increased imports of capital goods. The technological spillovers embodied in the imported capital goods raise TFP at sector level, especially in the export sector, which employs imported capital more intensively. A higher TFP level allows the export sector to expand, which implies more imported intermediates and capital. This induces more rapid TFP growth, making investments more profitable and further stimulating capital accumulation. The interplay between capital accumulation and productivity growth counteracts the decreasing return to capital and allows the economy to keep high growth over time. The economy converges to the designed long run rate of 5.5 percent. Figure 1 shows the actual and calibrated path of real GDP. The growth path of the model matches the actual development quite well during the period under study, although the particular growth boom driven by foreign investment in the late 1980s is not captured.

Figure 1 about here

As explained in Section 4, productivity growth in the export sector results from foreign spillovers embodied in imports of intermediates and capital, and this induces domestic spillovers to the rest of economy. Growth in productivity slows down with an increased productivity level, which is captured by a negative value of j in the sector productivity growth functions. These two forces imply that the growth rate in export sector's productivity increases from 1.6% to 3.2% during the first 30 years, and eventually falls back to 2.75%, which is the designed long-run growth rate for all sectors. As can be seen from Figure 2, productivity growth increases gradually in the first 30 years. The increased growth rate follows from the gradual accumulation of the imported capital stock. The level of productivity in the export sector more than doubles, and the magnitude of the spillover effect declines over time due to the lower learning potential. The TFP growth path is upward sloping and concave. Productivity growth increases over time, but at a declining rate due to the fishing out, and converges to a constant long run rate.

Figure 2 about here

Productivity growth in the other domestic sectors is driven by both domestic (through intermediate deliveries to the export sector) and foreign (through imports of intermediates and capital) spillovers. To capture the actual growth path, the effect of imported capital is assumed larger than the spillover from imported and domestic intermediates (which are set equal). Along the calibrated path the use of imported intermediates per unit of output is nearly constant, while intermediate deliveries to the exportable sector and the use of imported capital increase significantly (both in agriculture, importables and nontradables). According to the calibration, the technical progress rate in agriculture rises from 1.5% to 2.2 % during the period 1968 – 98, in importables from 1.5% to 2.9%, and in nontradables from 1.4% to 2.5%. The agricultural TFP growth rate averages about 2.2%, while exportables, importables and nontradables have about 1% TFP growth.

The economic structure started to change with the rapid growth, and a shift from a large and dominating agricultural sector to the export-oriented industrial sector is observed both in the data and in our calibration. In the model the structural change results from both supply and demand factors. The initial level of TFP in the export (agricultural) sector is set lower (higher) than in the other sectors, which implies that the endogenous labor augmenting productivity growth rate will be higher (lower) in the export (agricultural) sector. The within-period consumption function over the four goods reflects non-homothetic preferences, represented by a Stone-Geary demand system. The demand for the agricultural good is income inelastic. Constant minimum consumption is assumed for the agricultural demand, and when income grows over time, the share of the minimum consumption declines. The demand and supply factors working together generate significant changes in sectoral GDP shares (Figure 3). Along the calibrated growth path the agricultural share in real GDP is reduced from 29 percent to 19 percent during the first 30 years, while in the same period, the export sector's GDP share grows from 7 percent to 14 percent. According to national accounts data, agriculture accounted for 33 percent of GDP in 1968 and 11 percent in 1998.

Figure 3 about here

The structural shift implies labor movements from agriculture to exportables, while the employment share in both nontradables and importables remains fairly constant over time. Increased productivity growth has two opposite effects on employment. First, higher productivity growth allows for maintained growth in production with reduced work force. Second, higher productivity growth reduces the relative price and increases demand and hence expands production. The strength of this last effect depends on the substitution possibilities with foreign goods. To reproduce the actual growth pattern, the expansionary effect must dominate in the export sector, and the employment growth in this sector is high. In agriculture, on the other hand, the labor saving effect dominates. The demand for agricultural goods is income inelastic, and the employment share in agriculture falls over time. The employment share in the export sector increases from 11 percent to 19 percent, while it falls from 24 percent to 15 percent in agriculture. The calibrated employment shares for the export sector almost match the data of the SAMs for 1975 – 95, in which employment share in the export sector rose from about 10 percent to 20 percent.

To summarize, it is our understanding that the interplay between productivity growth and high investments, together with the structural shift from agriculture to exportables, has enabled Thailand to keep the extraordinary high growth rate in the last three decades. High productivity growth makes investments more profitable and diminishing return to capital hence can be avoided. High capital accumulation and expansion of the export sector in turn imply more spillovers from abroad through more imports. The model emphasizes the important role played by capital good imports, both in capital accumulation and as a source of foreign spillovers. The calculated path of capital accumulation in Figure 4 shows that the growth rate of imported capital was initially more than 20 percent, allowing for high growth in the early period.

Figure 4 about here

7. Counterfactual analysis -- reduced openness

The Thai economy has been outward oriented, and many 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). We investigate the role of the openness in the growth process by a counterfactual experiment. The openess of the economy is reduced by exogenously increasing tariff barriers on imports of exportable and importable goods. In the calibrated reference path discussed in the previous section, tariff rates are 6% and 9% for the exportable and importable goods, respectively, for the entire time period. In the counterfactual scenario, we permanently increase the tariff rate for the exportables to 28% and to 39% for the importables (equivalent to 3.5 times increase in tariff barriers). With this shock, the model generates new growth paths for capital accumulation, TFP and hence GDP that significantly departure from the calibrated reproduction of the actual growth (Figure 5). While the effect of trade liberalization on Thailand's economy has been investigated in a static general equilibrium framework (e.g., Karunaratne, 1999), we offer an investigation of the dynamic consequences.

Figure 5 about here.

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 less foreign spillovers due to reduced imports, feed back affecting 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 average total investment share of GDP during the first 30 years falls from 29 percent along the calibrated growth path to 26 percent with higher tariffs. This has significant consequences for productivity dynamics and thereby the GDP growth.

Given our productivity specifications, increased protectionism affects productivity growth directly by increasing barriers to technology adoption and limiting the transfer of foreign spillovers. This reduces productivity growth in all sectors, but especially in the export sector, where average technical progress rate in the first 30 years fall by 40 percent, from 2.8% in the reference path to 1.8% in the protection scenario. Increased protectionism reduces productivity growth by limiting the expansion of the TFP-leading export sector. As we mentioned before, along the calibrated path the GDP share of the exportable rose from 7 percent to 14 percent, while protectionism results in an exportable GDP share of only 10 percent after 30 years. Moreover, as seen from Figure 6, the effect of high tariffs on productivity is permanent, as reduced sector productivity growth rates and hence reduced GDP growth rate are observed in the long run.

Figure 6 about here

The fall in productivity growth, together with reduced capital accumulation and a smaller export sector, reduces the long-run growth rate to 4.9 percent, from 5.5 percent in the calibration scenario (Figure 5). Hence, protectionism has a long-run effect on economic growth, which creates a large permanent and increasing income gap between the two scenarios (Figure 7). If tariff rates were 3.5 times higher for exportables and importables than in the data since 1968, per capita income in 1998 would have been about 75% of its actual level in that year. The dynamic productivity and growth effects of the protection result from the interaction between investment and learning by doing from the spillovers. The model offers a lesson about how they work and how the dynamics of productivity and investment may accumulate and seriously affect growth over time.

Figure 7 about here

8. Concluding remarks

Understanding the mechanisms behind the remarkable economic growth of 6-7% achieved in Thailand during close to 40 years is the focus of our study. While the discussion of East Asian growth has been a conflict between capital accumulation and productivity stories, we analyze the general equilibrium interaction between endogenous productivity growth and capital accumulation. The analysis is motivated by the mechanisms from both new and old growth theory. ‘New’ long-run productivity growth generation and ‘old’ investment, structural change and catch up during transition are equally important in explaining the growth performance.

We develop an intertemporal, general equilibrium model which is formulated and calibrated to reproduce the growth path from mid-1960s to mid-1990s. Learning by exporting is modeled as the main vehicle of productivity growth through international technological spillover, and the export sector brings further productivity effects to the rest of economy both through domestic and foreign technical spillovers. Expansion of exportable industries results in an economic structural shift from agriculture to industrialized modern economy, which further enhances the growth. Overall, the study shows how rapid economic growth is prolonged by multisector productivity and investment dynamics in this open economy setting.

The importance of openness is developed in a counterfactual analysis, where protection holds back growth by serving as a barrier to technological spillovers. Protecting domestic industrial sectors lowers investment and productivity growth in the export sector first and then spills over to the other sectors in the economy. The endogenous productivity growth mechanisms imply that the growth rate of the economy is lowered in the entire time period studied in the model. An increase in tariffs for exportables and importables of about 30 percentage points reduces the long-run growth rate by about one percent in the experiment presented. The slow down of the growth rate is accompanied by a slow down of the structural shift and hence exportable sector’s contribution to the economy is further weakened. The analysis shows how catch-up and learning by exporting can be significantly affected by trade policy and the importance of openness for growth.

After the growth period highlighted in this paper, Thailand has experienced a serious growth setback with macroeconomic instability. It is of great interest to know whether the economy will return to the high growth path reproduced here or whether the structural conditions for growth has changed. This basic issue concerns the sustainability of growth and in particular of the productivity mechanism. Observers are worried about the future world market conditions for labor intensive industries and the lack of emphasis to human capital accumulation and research and development investment. The export oriented labor intensive growth success has resulted from a long period of learning which may have declining return over time. The recent theoretical analysis of Acemoglu et al. (2002) addresses the necessity of transforming from an investment based strategy with catching up to an innovation based strategy. This seems to be the challenge for Thailand now. When macroeconomic stability is reestablished, the open trade regime may give the necessary conditions for new growth based on profitable investments in human capital and R&D stimulating productivity growth further.

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Appendix: Calibration

Based on the SAM for 1998, the domestic savings rate is about 30 percent and the investments are 28 percent of GDP. Domestic investment goods account for 22 percent and foreign investment goods the remaining 6 percent. The economy has a current account surplus of 17 percent of GDP and hence domestic savings fully finance the investments. The agricultural value-added is 16 percent of GDP, nontradables 60 percent, exportables 14 percent, while importables represents the remaining 10 percent. The tariff rate (relative to imports) equals 9.5 percent for agricultural goods, 7.3 percent for nontradables, 6.2 percent for exportables and 8.7 percent on importables.

The long run growth path calibrated as supply side response to sectoral investment and productivity must be made consistent with the macroeconomic equilbrium as represented by the Euler equation ($r = (1+ r)(1+ g + n)^{s} - 1$). Given intertemporal elasticity of substitution of 1.5 and a time preference rate of 0.05, the long run domestic interest rate is equal to 14 percent. Marginal product of both domestic and foreign capital is assumed to be 0.18, while depreciation rate is set to 0.035. Then, with the long run assumptions, most parameters of the intertemporal part of the model can be calibrated from the SAM. Given marginal product of capital, the initial capital stocks are calculated based on capital income. Land use in agriculture is assumed to account for 50 percent of total agricultural capital stock. Investment is calibrated from equations (16) and (17), for given values of depreciation rates and long run growth rate. The shadow prices of capital, q_i, equal the firm values relative to the capital stock, and follow when we know the interest rate. The coefficients a_i in the capital adjustment cost functions are determined by the no-arbitrage long run conditions, equations (19) and (20). The initial level of foreign debt is set by (18) given data about trade deficit/surplus together with the long-run growth rate and interest rate. φ is set to –0.1 in all sectors. The γ values allocate the effects of the two sources of foreign spillover, and g_1 is set to 0.35 while g_2 is calculated consistent with the balanced growth restriction ($g_1 + g_2 = 1 - j$). Based on the assumed long run technological progress, initial values of the spillover variables and the initial level of productivity, the parameter d is calibrated.

Values of selected calibrated parameters

Definition	**Symbol in the model**	**Value**
Share of labor in: -agriculture	a_1	0.35
-exportables	$b_{1,ex}$	0.42
-importables	$b_{1,im}$	0.38
-nontradables	$b_{1,nt}$	0.33
Share of domestic capital in: -agriculture	a_3	0.29
-exportables	$b_{2,ex}$	0.20
-importables	$b_{2,im}$	0.50
-nontradables	$b_{2,nt}$	0.58
Share of imported capital in: -agriculture	$1 - a_1 - a_2 - a_3$	0.03
-exportables	$1 - b_{1,ex} - b_{2,ex}$	0.38
-importables	$1 - b_{1,im} - b_{2,im}$	0.13
-nontradables	$1 - b_{1,nt} - b_{2,nt}$	0.09
Share of land in agriculture	a_2	0.33
Share of imports in final demand: -agricultural good	b_{CDag}	0.16
-exportable good	b_{CDex}	0.36
-importable good	b_{CDim}	0.35
-nontradable good	b_{CDnt}	0.27

Share of imports in intermediate demand for agricultural good:	$b_{IT\,ag,j}$	
- from agriculture		0.21
- from exportables		0.26
- from importables		0.40
- from nontradables		0.13
Share of imports in intermediate demand for exportable good:	$b_{IT\,ex,j}$	
- from agriculture		0.38
- from exportables		0.47
- from importables		0.37
- from nontradables		0.38
Share of imports in intermediate demand for importable good:	$b_{IT\,im,j}$	
- from agriculture		0.42
- from exportables		0.49
- from importables		0.53
- from nontradables		0.39
Share of imports in intermediate demand for nontradable good:	$b_{IT\,nt,j}$	
- from agriculture		0.06
- from exportables		0.15
- from importables		0.06
- from nontradables		0.13
Share of exports in production: -agriculture	bx_{ag}	0.67
-exportables	bx_{ex}	0.51
-importables	bx_{im}	0.61
-nontradables	bx_{nt}	0.77
Share in total consumption demand		
- agricultural composite good	ac_{ag}	0.19
- exportable composite good	ac_{ex}	0.21
- importable composite good	ac_{im}	0.09
- nontradable composite good	ac_{nt}	0.51
Time preference rate	r	0.05
Depreciate rate	d	0.035
Intertemporal elasticity of substitution	s	1.51
Parameter in productivity function	g_1	0.35
Parameter in productivity function	g_2	0.75
Parameter in productivity function	j	-0.1

Figure 1. Real GDP: Data vs. model's calibrated path

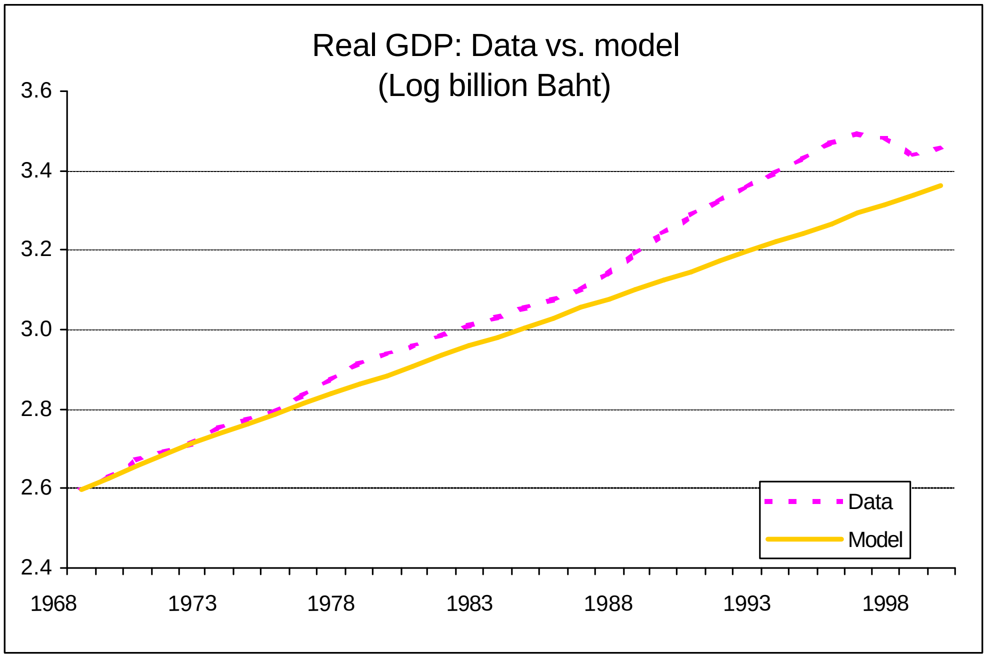


Figure 2. Sectoral labor augmenting technical progress along the growth path

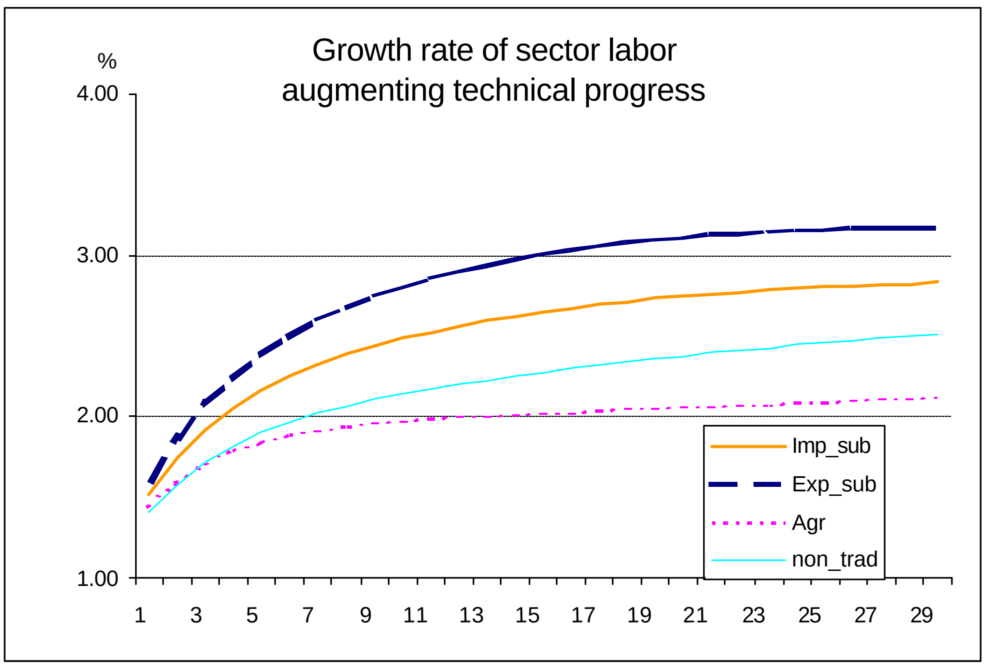


Figure 3. GDP shares along the growth path: exportables and agriculture

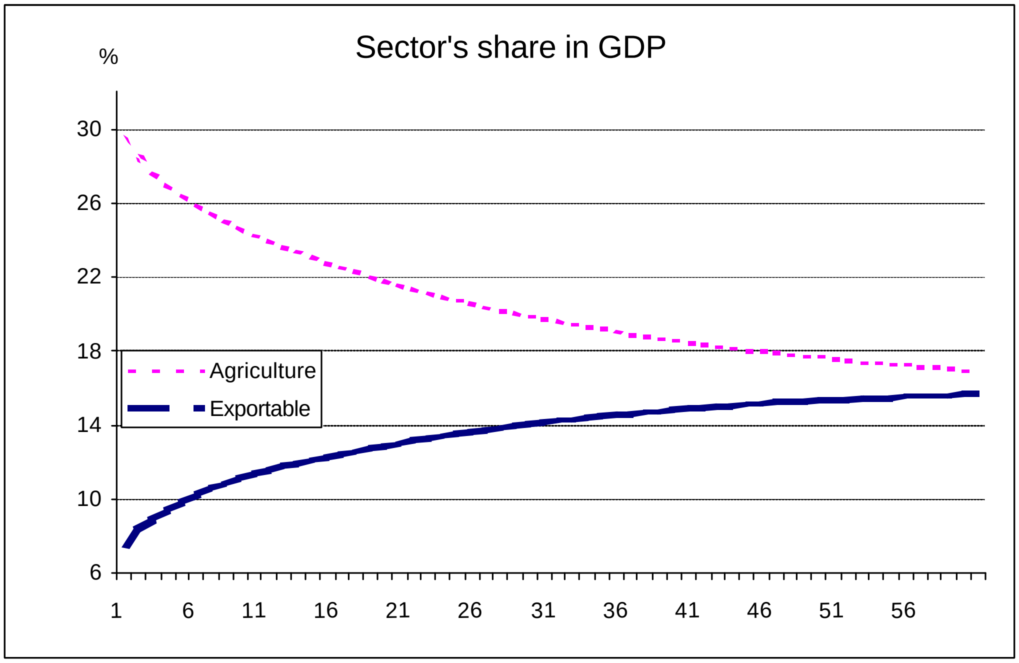


Figure 4. Growth rate of capital along the calibrated path: domestic vs. foreign

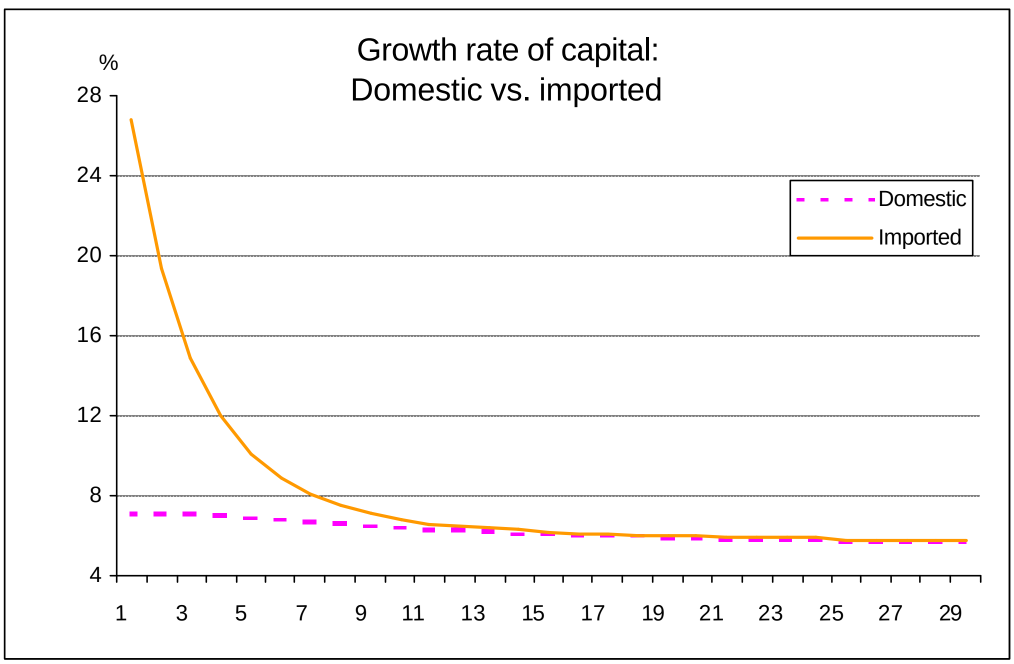


Figure 5. Growth rate of GDP: Calibrated path vs. protection path

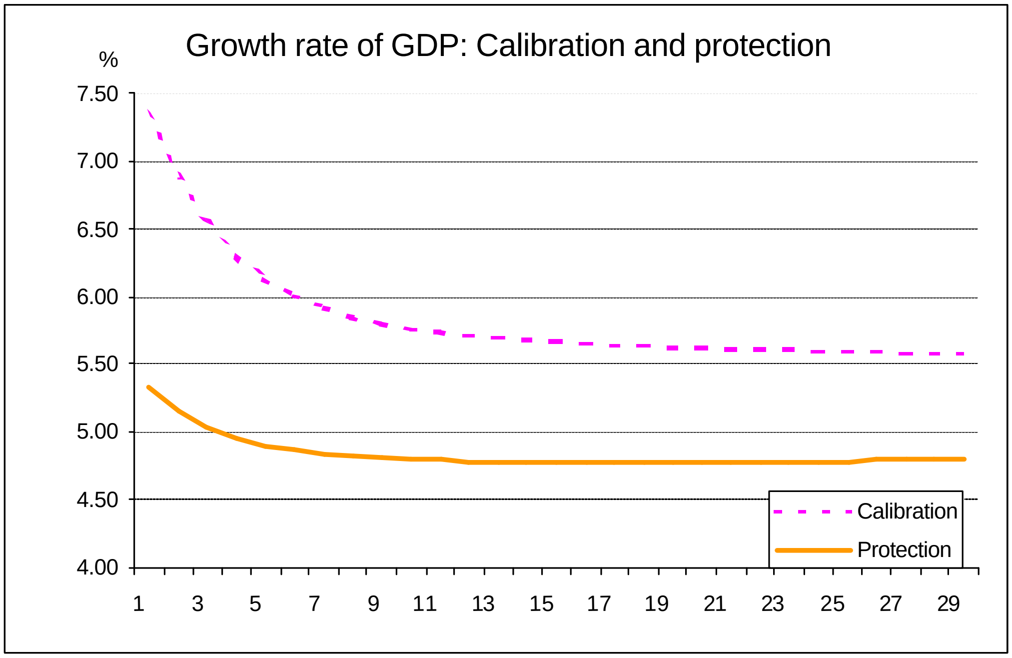


Figure 6. Labor augmenting technical progress in exportables and importables: calibrated path vs. protection path

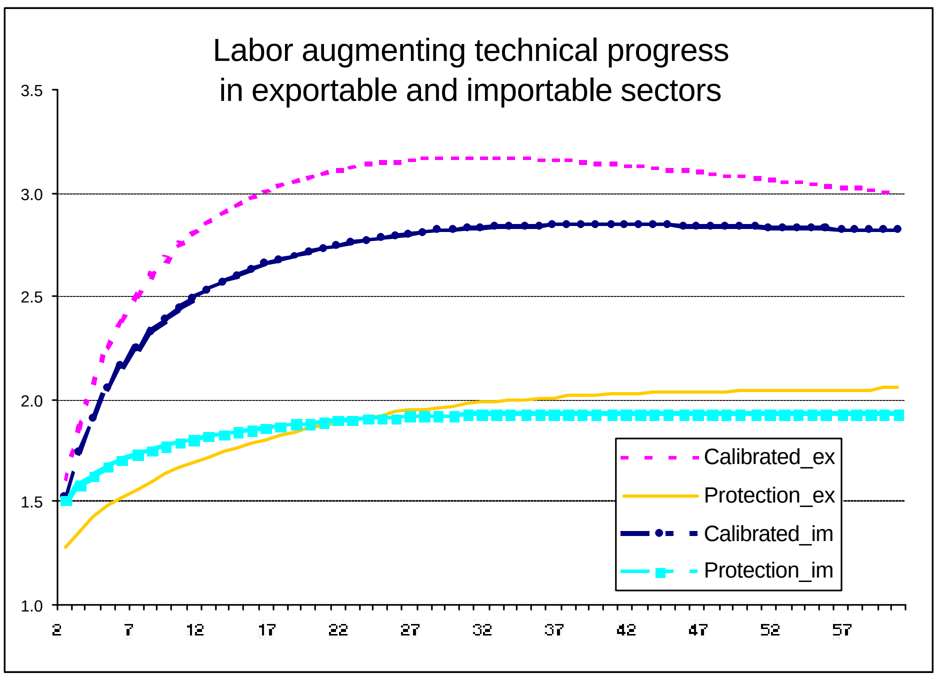
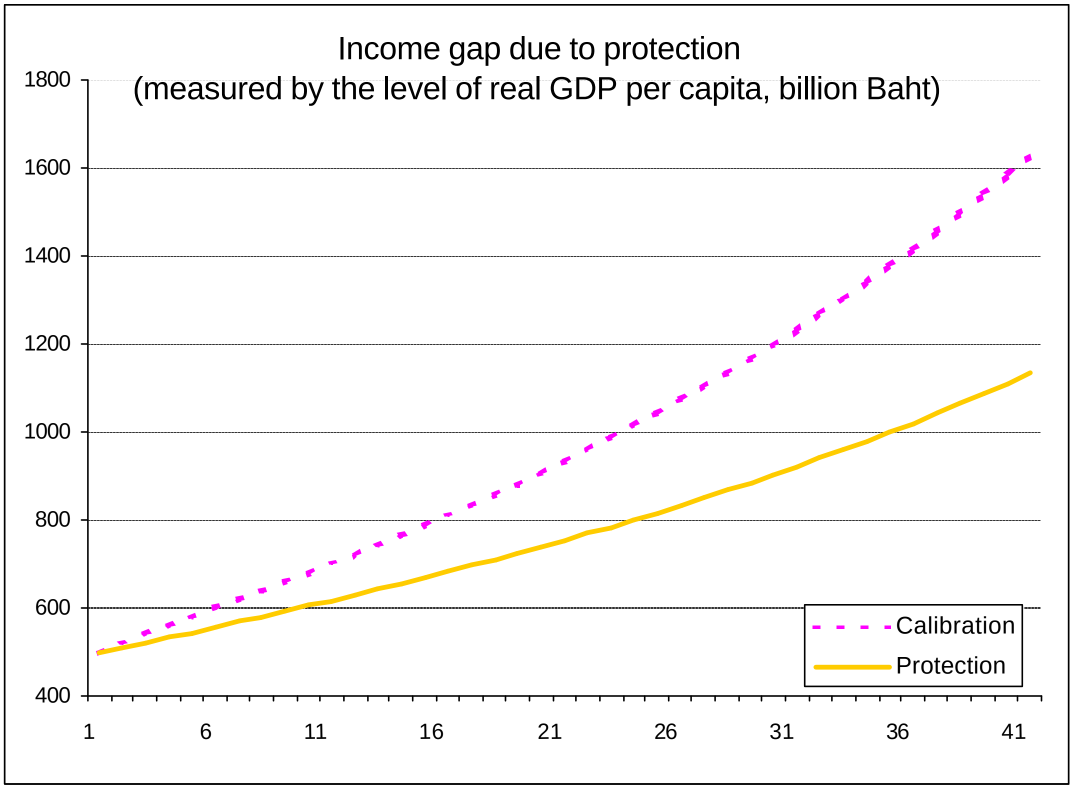


Figure 7. Income gap due to protection



Xinshen Diao, Jørn Rattsø and Hildegunn Ekroll Stokke,

Learning by exporting and productivity-investment interaction: An intertemporal general equilibrium analysis of the growth process in Thailand.

Date: October 11, 2002

Separate 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:

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

$$s.t.\ \ PQ_t \cdot Q_t = Y_t - SAV_t$$

U_1 is the value of the intertemporal utility evaluated at time period 1's price, and aggregate consumption, Q_t, for each time period is defined as:

$$Q_t = cs \cdot \prod_i (CD_{i,t} - q_i)^{ac_i}$$

where $CD_{i,t}$ is consumption for each good, q_i is the minimum consumption and is constant over time. Y_t is consumer's income for each period and is defined as:

$$Y_t = Wb_t L_t + Wd_t LD + Rk_{D,t} K_{D,t} + Rk_{M,t} K_{M,t} + FSAV_t + \sum_i atr_i \cdot PX_{i,t} \cdot X_{i,t} + \sum_i mtr_i \cdot PWM_i \cdot M_{i,t}$$

The Euler equation for the consumer problem is:

$$\left(\frac{Q_{t+1}}{Q_t} \right)^s = \frac{1+r_t}{1+r}$$

Consumer's demand for each commodity:

$$P\_CD_{i,t} \cdot (CD_{i,t} - q_i) = ac_i \cdot PQ_t \cdot Q_t$$

Production decision

The value-added production functions for the four sectors:

$$X_{i,t} = A_{i,t}^{b_{1,i}} L_{i,t}^{b_{1,i}} K_{D,i,t}^{b_{2,i}} K_{M,i,t}^{1-b_{1,i}-b_{2,i}} \qquad i = ex, im, nt$$
$$X_{ag,t} = A_{ag}^{a_1} A_D^{a_2} L_{ag,t}^{a_1} LD^{a_2} K_{D,ag,t}^{a_3} K_{M,ag,t}^{1-a_1-a_2-a_3}$$

First order conditions are:

$$b_{1,i} PV_{i,t} X_{i,t} = Wb_t \cdot L_{i,t}$$
$$a_1 PV_{ag\,t} X_{ag,t} = Wb_t \cdot L_{ag,t}$$
$$a_2 \cdot PV_{ag,t} \cdot X_{ag,t} = Wd_t \cdot LD$$
$$b_{2,i} PV_{i,t} X_{i,t} = Rk_{D,t} \cdot K_{D,i,t}$$
$$a_3 PV_{ag\,t} X_{ag,t} = Rk_{D,t} \cdot K_{D,ag,t}$$
$$(1 - b_{1,i} - b_{2,i}) PV_{i,t} X_{i,t} = Rk_{M,t} \cdot K_{M,i,t}$$
$$(1 - a_1 - a_2 - a_3) PV_{ag,t} X_{ag,t} = Rk_{M,t} \cdot K_{M,ag,t}$$

Value-added price for each sector:

$$PV_{i,t} = PX_{i,t}(1 - atr_i) - \sum_j P\_IT_{j,i,t} IO_{j,i} \qquad i = ag, ex, im, nt$$

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 stocks (domestic and foreign) over time:

$$\underset{I_k, K_k}{Max} \sum_{t=1}^{\infty} \frac{1}{\prod_{s=1}^{t}(1+r_s)} \sum_k [Rk_{k,t} \cdot K_{k,t} - (PI_{k,t} \cdot I_{k,t} + ADJ_{k,t})]$$

$$s.t.\ K_{k,t+1} = K_{k,t} \cdot (1 - d_k) + I_{k,t} \qquad k = D, M$$

where *I* is investment in quantity and *ADJ* is the adjustment costs and

$$I_{k,t} = A_k \cdot \prod_i IVD_{k,i,t}^{ak_{k,i}}$$

$$ADJ_{k,t} = a_k \cdot PD_{nt,t} \cdot \frac{I_{k,t}{}^2}{K_{k,t}}$$

The first order conditions:

$$q_{k,t} = PI_{k,t} + 2 \cdot PD_{nt,t} \cdot a_k \cdot \frac{I_{k,t}}{K_{k,t}}$$

$$r_t \cdot q_{k,t-1} = Rk_{k,t} + a_k \cdot PD_{nt,t} \cdot \left(\frac{I_{k,t}}{K_{k,t}}\right)^2 - d_k \cdot q_{k,t} + \dot{q}_{k,t}$$

Demand for investment goods is:

$$PD_{i,t} \cdot IVD_{D,i,t} = ak_{D,i} \cdot PI_{D,t} \cdot I_{D,t}$$

$$PWM_i(1+mtr_{i,t}) \cdot IVD_{M,i,t} = ak_{M,i} \cdot PI_{M,t} \cdot I_{M,t}$$

The adjustment costs consume the non-tradable good, hence total investment demand for this good has to include the adjustment cost:

$$TIVD_{D,nt,t} = IVD_{D,nt,t} + \sum_k ADJ_{k,t} / PD_{nt,t}$$

Exports and Imports

Domestic and imported consumption and intermediate goods are imperfect substitutes, and demand is determined endogenously from minimizing current expenditure subject to the Armington function.

Final consumption:

$$Min \;\; PM_{i,t} \cdot M_{cd,i,t} + PD_{i,t} \cdot D_{cd,i,t}$$

$$s.t. \;\; CD_{i,t} = a_{CD_i}[b_{CD_i} \cdot M_{cd,i,t}^{-exa\_CD} + (1-b_{CD_i}) D_{cd,i,t}^{-exa\_CD}]^{-1/exa\_CD}$$

where

$PM_{i,t} = PWM_i(1+mtr_{i,t})$ is the price of foreign goods.

The first order conditions:

$$\frac{M_{cd,i,t}}{CD_{i,t}} = a_{CD_i}^{\frac{-exa\_CD}{exa\_CD+1}} \cdot \left(b_{CD_i} \frac{P\_CD_{i,t}}{PM_{i,t}} \right)^{\frac{1}{exa\_CD+1}}$$

$$\frac{D_{cd,i,t}}{CD_{i,t}} = a_{CD_i}^{\frac{-exa\_CD}{exa\_CD+1}} \cdot \left((1-b_{CD_i}) \cdot \frac{P\_CD_{i,t}}{PD_{i,t}} \right)^{\frac{1}{exa\_CD+1}}$$

where $exa\_CD = \frac{1}{s_{CD}} - 1$.

<u>Intermediate demand:</u>

$$Min \;\; PM_{i,t} \cdot M_{i t i,j,t} + PD_{i,t} \cdot D_{i t i,j,t}$$

$$s.t. \;\; IT_{i,j,t} = a_{IT_{i,j}} [b_{IT_{i,j}} \cdot M_{i t i,j,t}^{-exa\_IT} + (1-b_{IT_{i,j}}) D_{i t i,j,t}^{-exa\_IT}]^{-1/exa\_IT}$$

The first order conditions:

$$\frac{M_{i t i,j,t}}{IT_{i,j,t}} = a_{IT_{i,j}}^{\frac{-exa\_IT}{exa\_IT+1}} \cdot \left(b_{IT_{i,j}} \frac{P\_IT_{i,j,t}}{PM_{i,t}} \right)^{\frac{1}{exa\_IT+1}}$$

$$\frac{D_{i t i,j,t}}{IT_{i,j,t}} = a_{IT_{i,j}}^{\frac{-exa\_IT}{exa\_IT+1}} \cdot \left((1-b_{IT_{i,j}}) \cdot \frac{P\_IT_{i,j,t}}{PD_{i,t}} \right)^{\frac{1}{exa\_IT+1}}$$

where $exa\_IT = \frac{1}{s_{IT}} - 1$.

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:

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

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

where $PE_i = PWE_i$ is the export price.

The first order conditions:

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

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

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

Domestic demand is given as

$$D_{i,t} = \sum_j D_{it,i,j,t} + D_{cd,i,t} + TIVD_{D,i,t}$$

Foreign borrowing and foreign debt

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

$$M_{i,t} = \sum_j M_{it,i,j,t} + M_{cd,i,t} + TIVD_{M,i,t}$$

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

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

Factor market equilibrium

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

$$K_{k,t} = \sum_i K_{k,i,t} \qquad k = D, M$$

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

Endogenous productivity

Sectoral productivity growth is endogenously driven by learning from abroad through foreign capital and intermediate goods, and domestic spillovers through interactions with the exportable sector.

$$\left(\frac{\dot{A}_{ex}}{A_{ex}}\right)_t = d_{ex}\frac{\left(\sum_i M_{it,i,ex,t} \big/ L_t\right)^{g_{1,ex}} \left(K_{M,ex,t} \big/ L_t\right)^{g_{2,ex}}}{A_{ex,t}^{1-j_{ex}}}$$

$$\left(\frac{\dot{A}_j}{A_j}\right)_t = d_j\frac{\left((D_{it,j,ex,t} + M_{it,ex,j,t}) \big/ L_t\right)^{g_{1,j}} \left(K_{M,j,t} \big/ L_t\right)^{g_{2,j}}}{A_{j,t}^{1-j_j}}, \text{ for } j = ag,\ im,\ nt.$$

$$g_t = \sum_i s_{i,t}\left(\frac{\dot{A}_i}{A_i}\right)_t, \text{ where } s_{i,t} = \frac{PX_{i,t}X_{i,t}}{GDP_t}$$

Land augmenting technical change is assumed consistent with a balanced growth path.

$$\left(\frac{\dot{A}_D}{A_D}\right)_t = \left[\left(\frac{\dot{A}_{ag}}{A_{ag}}\right)_t + 1\right]\cdot(1+n)-1$$

Endogenous domestic interest rate consistent with endogenous productivity growth:

$$r_t = d\left(\frac{1/2\cdot\sum_i (E_{i,t} + M_{i,t})}{GDP_t}\right)^e$$

Terminal conditions (long run 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 long run situation.

$$I_{k,T} = (d_k + g_T + n)K_{k,T}$$

$$FSAV_T = (g_T + n - r_T)DEBT_T$$

$$Rk_{k,T} - a_k \cdot PD_{nt,T}\left(\frac{I_{k,T}}{K_{k,T}}\right)^2 = (r_T + d_k)q_{k,T} \qquad k = D, M$$

These conditions state that foreign debt and capital stocks grow at a constant rate (endogenously determined) given by $g_T + n$, and that marginal return to capital becomes constant.

To have consumption growth consistent with the economy wide growth rate the following relationship between interest rate and growth rate has to hold in the long run:

$$\left(1+g_T+n\right)^s = \frac{1+r_T}{1+r}$$

A.2 Glossary

Parameters

$b_{1,i}$	share parameter for labor in value added function sector *i*, *i = ex, im, nt*
$b_{2,i}$	share parameter for domestic capital in value added function sector *i*, *i = ex, im, nt*
a_1	share parameter for labor in agricultural value added function
a_2	share parameter for land in agricultural value added function
a_3	share parameter for domestic capital in agricultural value added function
IO_{ij}	input-output coefficient for commodity i used in sector j
exa_CD	exponent in Armington function consumption demand
s_{CD}	elasticity of substitution between imported and domestic consumption goods
b_{CD_i}	share parameter in Armington function for imported consumption good i
a_{CD_i}	shift parameter in Armington function for consumption commodity i
exa_IT	exponent in Armington function intermediate demand
s_{IT}	elasticity of substitution between imported and domestic intermediate goods
$b_{IT\,i,j}$	share parameter in Armington function for imported intermediate good i sector j
$a_{IT\,i,j}$	shift parameter in Armington function for intermediate commodity i sector j
exc	exponent in CET functions
s_e	elasticity of substitution between domestic goods and exports
bx_i	share parameter in CET function for export good i
ax_i	shift parameter in CET function for commodity i
$a\,c_i$	share of consumer's demand for commodity i
cs	shift parameter in total consumption function
A_k	shift parameter in total investment function capital good k, $k = D, M$
$a\,k_{k,i}$	share of investment demand capital good k for commodity i
a_k	coefficient in adjustment cost function
r	rate of consumer's time preference
σ	intertemporal elasticity of substitution
d_k	depreciation rate capital good k
$g_{1,i}$	coefficient in labor augmenting technical progress function
$g_{2,i}$	coefficient in labor augmenting technical progress function
j_i	coefficient in labor augmenting technical progress function
d	parameter in interest rate function
e	elasticity in interest rate function

$s_{i,t}$	value added share sector *i*

Exogenous variables

LD	land supply
PWM_i	world import price for commodity *i*
PWE_i	world export price for commodity *i*
atr_i	sales tax rate for commodity *i*
mtr_i	tariff rate for commodity *i*
q_i	minimum consumption good *i*
n	exogenous labor supply growth rate
L_t	labor supply

Endogenous variables

$X_{i,t}$	output of commodity *i*
$K_{k,i,t}$	sector's demand capital good *k*
$L_{i,t}$	sector's labor demand
$D_{i,t}$	good *i* produced and consumed domestically
$M_{i,t}$	imports of commodity *i*
$E_{i,t}$	exports of commodity *i*
$CD_{i,t}$	consumer's demand for good *i*
$M_{cd,i,t}$	consumer's demand for foreign good *i*
$D_{cd,i,t}$	consumer's demand for domestic good *i*
$IT_{i,j,t}$	intermediate demand for good *i* from sector *j*
$M_{it,i,j,t}$	intermediate demand for foreign good *i* from sector *j*
$D_{it,i,j,t}$	intermediate demand for domestic good *i* from sector *j*
$IVD_{k,i,t}$	investment demand capital *k* commodity *i*
$TIVD_{k,i,t}$	total investment demand including adjustment costs
$I_{k,t}$	investment in quantity
$K_{k,t}$	capital stock
$ADJ_{k,t}$	adjustment costs
Q_t	aggregate consumption
Y_t	consumer's income
SAV_t	consumer's savings
GDP_t	GDP
$FSAV_t$	trade deficit

$DEBT_t$	foreign debt
$PV_{i,t}$	value added price for commodity i
Wb_t	wage rate
Wd_t	land rental rate
$Rk_{k,t}$	rate of return to capital
$PX_{i,t}$	producer price for commodity i
PQ_t	aggregate consumption price
$P\_CD_{i,t}$	Armington composite price for consumption commodity i
$P\_IT_{i,j,t}$	Armington composite price for intermediate commodity i employed by sector j
$PD_{i,t}$	price for D_{i}
$PM_{i,t}$	import price for commodity i
PE_i	export price for commodity i
$PI_{k,t}$	unit cost of investment that builds up capital equipment
$q_{k,t}$	shadow price of capital
r_t	domestic interest rate
$A_{i,t}$	labor augmenting technical progress
$(A_D)_t$	land augmenting technical progress