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Learning and Foreign Technology Spillovers in Thailand: Empirical Evidence on Productivity Dynamics

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Thailand has experienced annual average growth of GDP of remarkable 6.6% during the period 1950 – 2000. We analyze total factor productivity (TFP) growth in a modified Nelson-Phelps framework where foreign trade and foreign direct investment influence the adoption of technology. The econometric analysis separating between sources of productivity for agriculture and industry covers the period 1975 – 96. International spillovers are significant and important, and both sectors have been able to take benefit of openness. The analysis addresses the endogeneity issues involved in the estimation of TFP sources and investigates the dynamics of productivity. The effects during the period studied must be interpreted as transition growth, and endogenous growth effects are rejected. JEL – codes: O47, O53.

After a couple of decades of renewed interest in economic growth mechanisms, the focus of empirical analyses again is turned to productivity. Countries seem to have permanent differences in productivity (Hall and Jones, 1999). While the evidence collected and analyzed basically has been of the cross-country variety, we offer time series analysis of a country with an extraordinary stable growth record, Thailand. The average annual growth rate of GDP during the period 1950–2000 has been remarkable 6.6% (Jansen, 2001).

The endogenous growth literature has concentrated on human capital development and resources allocated to research and

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development. While these factors certainly are of interest in Thailand, we hypothesize that the productivity growth process is more linked to learning and imitation from abroad. The productivity growth is stimulated by international competition and adoption of existing international technologies and is channeled through foreign trade and foreign investment. The background inspiration for the study is learning by doing (LBD) and the role of international spillovers in the tradition of Arrow (1962) and Nelson and Phelps (1966). Given global R&D and world technology, productivity dynamics results from foreign spillovers and domestic structural shift.

Transformation from agriculture to industry is an essential aspect of growth in all developing countries. Governments influence this transformation by an array of policies affecting sectoral balance, including taxation, investment financing, price regulation, and protectionism. The contrasting views of this transformation were particularly stark in the Soviet debate after the revolution, and Thailand seems to have followed the recipe of Preobrazhensky (1926), which is given a modern restatement for open economies by Matsuyama (1992): Stimulate industry. The development strategy assumes competition between agriculture and industry for labor and capital, and in Thailand the absorption of labor in labor-intensive industries has been essential. In our context, the sectoral balance and the foreign linkages are determinants of technology spillovers driving economic growth.

During the growth period of the last 50 years, Thailand was transformed from a 'rice economy' to industrialization. The country always was oriented towards the world market, but the export composition shifted from primary goods to labor-intensive industrial products. Interestingly, in a longer time perspective Thailand experienced deindustrialization from domestically oriented rural industries with specialization in rice exports (during the period 1870 to World War II). The more recent transformation shifted exports from agriculture to industry. The productivity consequences of this transformation are addressed here.

The broad empirical background for our analysis is the debate about the East Asian 'miracle'. Young (1994) challenges the understanding that the regional growth rates are a miracle. In a growth accounting framework he finds that high investment explains most of the growth, not rapid technological progress measured as total factor productivity (TFP). Young has been criticized on both empirical and theoretical grounds. Rodrik (1998) shows how the growth accounting can underestimate the role of TFP when the elasticity of substitution between capital and labor is less than 1 (and not equal to 1 as in the Cobb-Douglas case). Hulten (2001) more broadly argue that TFP will be underestimated since TFP induces capital accumulation. Studies of Thailand tend to find significant total factor productivity growth anyway, and our analysis looks at sources of this TFP growth related to international spillovers and learning.

The empirical analysis of TFP in this paper serves as input to an economy-wide intertemporal general equilibrium model of Thailand to do counter-factual analyses of the growth process. The first analysis of transition growth in a model with endogenous productivity is presented by Diao, Rattsø and Stokke (2002), and is related to the literature on short versus long run welfare effects of trade liberalization. Diao, Roe and Yeldan (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 manufacturing expansion, but then crowds out foreign spillovers over time. Compared to Japan, Thailand's trade protection has concentrated more on industry than agriculture. Rauch (1997) finds 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. Diao, Rattsø and Stokke find that trade liberalization promotes growth both in the short and the long run in Thailand because of the foreign spillovers encouraged by expanding trade. This paper offers some evidence on this spillover.

The next section summarizes the present understanding of the growth process in Thailand including econometric evidence about spillovers. Then the theoretical framework of TFP growth is described, and data and econometric specification are discussed. Results from the estimation of productivity growth relationships are presented and discussed, and concluding remarks are given in the last section.

Thailand productivity growth and spillovers

The average annual growth rate of GDP of 6.6% during the period 1950–2000 is remarkable in any international comparison (Jansen, 2001). The growth has been steady and with macroeconomic stability (up till the recent 'crisis'). During the most spectacular period, 1987 to 1995, the annual GDP growth was at 11% (Limskul, 1995). Observers seem to agree that the growth process started with investment in industrialization and export orientation. European and Chinese merchants played an important role and the shift towards industry came after a long period of extension of agricultural land.

Growth accounting analyses of Thailand have been abundant as part of the controversy over the broader East Asian experience. 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% (1970–85). In a reanalysis for a longer time-period, 1960–94, Collins and Bosworth (1996) confirm the estimated TFP growth of close to 2%. Tinakorn and Sussangkarn (1998) report from 10 studies where TFP growth estimates vary from 0.5% to 2.7%, that is from 7 to 40% of the overall growth (of 7%). Their own analysis of new GDP data for 1980–95 find TFP growth of about 2%, although 40% of this can be explained by improved labor quality. In an extension of the analysis they include land as production factor and adjustment of labor input for changes in education, age and sex composition. TFP growth then is down to 1.3%.

The growth process and the productivity growth have not been balanced across sectors. Again there is some controversy in the empirical evaluation. Limskul (1995) reports results from an analysis of the period 1970-85, when annual agricultural growth was 4%, while the annual growth of manufacturing industries was 9%. According to the estimates, TFP growth in agriculture is negative (-0.2%), but positive in manufacturing (1.7%). Adjusting for labor quality and including land, Tinakorn and Sussangkarn (1998) estimate sectoral TFP growth of 1% in agriculture and zero in manufacturing industries (for 1981–95). Their interpretation of the low TFP growth in manufacturing is the importance of technological progress embodied in imported capital. Uruta and Yokota (1994) find that TFP growth in manufacturing has fallen from 1.8% 1976–82 to 0.7% 1982–88 when they take into account intermediate inputs explaining most of the growth.

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. Tinakorn and Sussangkarn (1998) relate annual aggregate TFP growth 1981–95 to the capital stock, the openness of the economy, and the sectoral allocation of employment. The effect of the two first variables can be interpreted as learning by doing and foreign spillover, and both effects are statistically significant. They also show a positive effect of the share of employment outside agriculture implying that industrial structure matters. Uruta and Yokota (1994) find that TFP growth in manufacturing increases with trade liberalization (measured by effective rates of protection). These analyses provide an interesting starting point for generalizations about the technological progress. Our analysis can be seen as an extension of Tinakorn and Sussangkarn (1998) using a longer time period, new data, and a separation between agriculture and industry (rest of the economy).

Framework for the analysis of learning and spillovers

The starting point of our analysis is the understanding that productivity growth in Thailand takes the form of learning rather than based on own research and development. Arrow (1962) innovated the understanding of LBD as an additional benefit or spillover of capital accumulation. The engine of growth in his model is LBD in the capital goods industry. The learning is external and like a public good, and the efficiency from the producer point of view depends on the cumulative aggregate output of capital goods. We will keep this externality understanding of LBD, but will use a more general growth specification.

In the Thailand context, the learning seems to be related to interaction with the world market, that is foreign spillover. The background literature has concentrated on the foreign technology gap, and Krugman (1979) formulates technology diffusion associated with international trade, specifically as 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.

Given that technology presumably is common knowledge at the world scale, productivity growth is about adopting world technology at the country level. Nelson and Phelps (1966) innovated the understanding of the technology gap and emphasized skill as the major constraint. They assume exogenous growth of the world technology frontier T, and formulate the growth of TFP measured as A in a one sector economy as:

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

The parameter ϕ depends on human capital, and captures the assumption that the human capital stock influences the ability to benefit from world technology. A dot over a variable indicates change from one period to the next. With this formulation, the TFP growth is faster the further the economy is away from the world frontier. When the gap is larger, there is more to catch up. Acemoglu and Zilibotti (2001) is a modern restatement of the role of skills, with directed technical change in the North and the South importing technologies developed in the

North. The skill-bias of the technology makes it less useful in the South and may lead to prolonged productivity differences. Parente and Prescott (1994) present an alternative influential understanding of technology adoption related to 'barriers'. Improvement of productivity relative to the frontier requires investment costs, and the authors assume that policy induced distortions explain most of these costs and therefore why countries lag behind.

Following Edwards (1998), many authors have investigated the linkage between openness and productivity in cross-country analyses. The two channels of spillovers dominating are international trade (Coe, Helpman and Hoffmaister, 1997) and foreign direct investment FDI (Borensztein, De Gregorio and Lee, 1998). Borensztein et al. study the link between FDI and economic growth, and they suggest testing the effect of FDI on TFP, as followed up here. FDI is measured relative to total investment (I). There has been some debate about the role of exports and imports for spillovers, and Coe et al. study spillovers through imports of machinery and equipment, taking into account the R&D intensity of the country's trading partners. We choose a more general approach relating foreign spillovers to the openness of the economy, measured here by total trade (exports EX + imports IM) as share of GDP (Y). The growth rate of productivity is:

$$\frac{\dot{A}_t}{A_t} = \phi\left(\frac{EX + IM}{Y}, \frac{FDI}{I}\right)\left(\frac{T_t - A_t}{A_t}\right)$$

The dynamics imply constant long run productivity growth equal to the growth of the world technology frontier, giving a constant equilibrium gap (as in the Nelson-Phelps model). The shares are assumed to contribute positively to the catch up (ϕ'>0 and ϕ''< 0 in both arguments), but are constant in the long run and only affect productivity level and equilibrium gap. The dynamic specification and in particular the alternative assumption of endogenous growth will be tested below. Our benchmark empirical model assumes that increasing trade shares are increasing TFP levels.

Several recent dynamic analyses of productivity take into account domestic sectoral interaction. Krugman (1987) and van Wijnbergen (1984), and later Matsuyama (1992) and Sachs and Warner (1995) in endogenous growth models, assume that knowledge accumulates as a byproduct of experience in industry. Krugman, van Wijnbergen and Matsuyama hold agricultural productivity constant, while Sachs and Warner assume a perfect spillover from industry to the rest of the economy. Rattsø and Torvik (2003) assume that industry is the potentially leading sector in terms of productivity growth and learning by doing, but assume that agriculture may take benefit of catching up. In their model the technology gap concept concerns the relation between industrial and agricultural productivity. Sectoral learning by doing is investigated by including labor shares of the two sectors in the analysis below. The combination of econometric challenges (endogeneity) and data limitations have not allowed for a thorough investigation of the intersectoral aspects. We have experimented with a measure of human capital, average school years in the population, but never found any effect of this variable.

Econometric formulation

The first step of the analysis is to measure the TFP growth in agriculture and industry. Based on the Cobb – Douglas production function, annual sectoral TFP growth rates for the period 1972–96 are calculated as the difference between growth in real value added and real factor accumulation:

$$\frac{\dot{A}_M}{A_M} = \frac{\dot{X}_M}{X_M} - \alpha \frac{\dot{L}_M}{L_M} - (1-\alpha)\frac{\dot{K}_M}{K_M}$$

$$\frac{\dot{A}_A}{A_A} = \frac{\dot{X}_A}{X_A} - \beta_1 \frac{\dot{L}_A}{L_A} - \beta_2 \frac{\dot{LD}}{LD} - (1-\beta_1-\beta_2)\frac{\dot{K}_A}{K_A}$$

where A_i is TFP level, X_i is output, L_i labor use and K_i capital stock sector i, i = agriculture A and industry M. LD is land input in agriculture, while α, β_1 and β_2 are constant factor shares. Description of data sources and definitions are given in appendix A.

Annual factor shares in agriculture, industry and service for the period 1980–95 are given by Tinakorn and Sussangkarn (1998), and they fluctuate with no clear trend. Based on value added shares in industry and service as weights we calculate factor shares for an aggregate industry sector, and together with the given shares for agriculture, we use the average of these factor shares as a proxy for the period 1972–96. We normalize the productivity level in both sectors to one in 1971, and then utilize annual growth rates to calculate the evolvement of sectoral productivity over time (shown in appendix C).

The ambition of the econometric formulation is to study how sectoral productivity levels and growth rates are affected by foreign spillovers and learning by doing. To separate between short and long run effects and investigate the dynamics, we apply an error correction model. Full econometric specification of our modified Nelson-Phelps framework is given in appendix B, with trade share, FDI share and labor shares as the main determinants. It should be noticed that we exclude the technology gap as an independent variable, assuming that it has been large all through the period studied. Hall and Jones (1999) measure Thailand's productivity level to about 50% of the US in 1988. Since about 99% of all foreign direct investments in Thailand are made in the industrial sector, this variable is not expected to affect agricultural productivity. Change in capacity utilization is included to correct for business cycles in industry, as applied by Jonsson and Subramanian (2001). Short run fluctuations in TFP do not necessary reflect technology changes, but might be due to business cycle effects. When short run adjustments of the capital stock are hard to do and the labor market is inflexible, TFP will typically be higher during booms, and equivalent lower during recessions.

The error correction model includes an immediate effect of the independent variables that is carried forward by a partial adjustment mechanism (by the lagged endogenous variable). The interpretation of a positive short run coefficient is a temporary effect on the productivity level that gradually disappears. The long run effect means that a higher level of independent variables brings with it a higher level of productivity. In the benchmark formulation we use share variables, and in our dataset both trade as share of GDP and foreign direct investments relative to gross capital formation are increasing over time. Hence, the economy is not in its long run equilibrium with constant share variables, but rather in transition towards steady state. It follows that the estimated long run effects of these variables on productivity reflect transition. We investigate an alternative dynamic formulation, where the independent variables are specified as level variables (total trade and foreign direct investment, both in real terms). The level variables will grow in the steady state, and a significant long run effect implies that productivity will grow with them. This separation between transition and steady state dynamics is often neglected in the literature. Finally, and closer to the modified Nelson-Phelps model introduced above, we test for endogenous growth rate effect by running regressions with productivity growth rate as dependent variable (using log-linear approximation). This estimation shows whether an increase in foreign spillover variables (trade/GDP and FDI/I) have temporary or permanent effects on productivity growth.

Since the focus of the empirical analysis is on interactions and effects between macroeconomic variables such as productivity, foreign trade, labor input, capacity utilization and foreign direct investments, our main econometric challenge is the possibility of biased estimates due to simultaneity problems. The causality might as well go from TFP to trade, instead of openness leading to higher productivity. As shown by Bernard and Jensen (1999) this relationship apply in the US manufacturing, where the understanding is that highly productive firms are more likely to enter the export market. The critique of foreign trade as independent variable in TFP regressions might be less valid when it comes to developing countries. Applying micro data for Thailand, Hallward-Driemeier, Iarossi and Sokoloff (2002) show how firms interacting with the world market through exports have higher productivity. They identify firms that began as exporters and conclude that they have higher productivity years later compared to firms oriented towards the domestic market. However, we still try to control for this possible endogeneity relationship in the empirical analysis. Our first attempt is to include an extra lag of the trade variable, but to test the robustness of our results we also estimate the effects of import tariffs on productivity. Tariffs are policy determined and not clearly related to productivity. When it comes to labor, we try a simple way around the problem, measuring the LBD – effect by labor share instead of level, and adding an extra lag in the variable. In a cross-country study, Frankel and Romer (1999) apply a country's geographical characteristics as an instrument variable for trade. Controlling for endogeneity with instrument variables is hard to do in time-series analysis of one country.

Most of the productivity dynamics literature is theoretical, and confrontation with data raises some puzzles. The sectoral labor input influences the sectoral measure of TFP while at the same time being the source of learning. Foreign direct investments are one of the main channels for spillovers affecting domestic TFP, but might also contribute to higher economic growth through profitable reallocations of capital and labor. This can be made explicit by introducing the productivity relations into the relevant production functions, which is an interesting extension for future work. To study the magnitude and importance of spillovers and learning between domestic sectors it would be preferable with more disaggregated data, since the main part of domestic spillovers is likely to take place between sectors in our aggregate industry sector. This paper focuses on spillovers from abroad and within sector LBD, leaving spillovers and learning between domestic sectors for future research. Further investigation of the dynamics requires a longer data

Table 1.
Determinants of Total Factor Productivity in agriculture

Dependent variable: $\Delta(A_A)_t = (A_A)_t - (A_A)_{t-1}$. Period: 1975–96.

	1	2	3	4	5	6
Constant	0.376	0.594**	0.591**	0.706**	0.608**	0.594**
	(0.854)	(2.595)	(2.536)	(2.218)	(2.427)	(2.480)
$(A_A)_{t-1}$	-0.501**	-0.518**	-0.493**	-0.432**	-0.479**	-0.458**
	(-2.347)	(-2.541)	(-2.419)	(-2.280)	(-2.382)	(-2.394)
$\Delta\,[(EX+IM)/Y]_t$	0.250	0.361				
	(0.722)	(1.171)				
$[(EX+IM)/Y]_{t-1}$	0.221*1)	0.164**1)				
	(1.500)	(1.529)				
$\Delta[(EX+IM)/Y]_{t-1}$			0.509			
			(1.289)			
$[(EX+IM)/Y]_{t-2}$			0.107			
			(0.914)			
$\Delta\,(L_A/L)_{t-1}$	0.366					
	(0.839)					
$(L_A/L)_{t-2}$	0.262					
	(0.523)					
$\Delta(\text{tariff})_t$				0.009		
				(0.006)		
$(\text{tariff})_{t-1}$				-1.271*1)		
				(-1.350)		
$\Delta(EX+IM)_t$					0.0019	
					(0.903)	
$(EX+IM)_{t-1}$					0.0004	
					(0.964)	
$\Delta(EX+IM)_{t-1}$						0.0060
						(1.521)
$(EX+IM)_{t-2}$						-0.0004
						(-0.521)
R^2	0.31	0.28	0.26	0.23	0.25	0.29
DW	2.09	2.12	2.30	2.31	2.15	2.27

t – statistics in parenthesis. *** – The variable is significant at 1% level. ** – The variable is significant at 5% level.
* – The variable is significant at 10% level. 1) The significance relates to the long run solution.

series, which would allow for a test of the important proposition of Young (1991) that learning effects are declining over time.

Empirical evidence on foreign spillovers and LBD

We start out with direct OLS estimation of our benchmark formulation given in Appendix B, and then look at alternative specifications. The alternatives are motivated by our concern for endogeneity of the independent variables and general robustness of the results. The estimates provide interesting insight into the productivity dynamics, and the dynamic adjustment processes are generally satisfactory, but as will come clear there are some challenges to robustness.

Short and long run elasticities are calculated based on average variable values for the period 1975–96, given in Appendix D.

Agriculture

The estimates of TFP sources in agriculture are reported in Table 1, where the benchmark specification is shown in the first column. The short and long run effect of agricultural labor share, representing possible within sector LBD, is positive, but not significant. The coefficients vary a lot across specifications, even with negative effect in some cases, and seldom come out as significant. Hence, we do not find any evidence of LBD in agriculture driven by labor use. This might be due to wrong econometric specification of the learning effect, and alternative formulations should be pursued in the future. Regarding foreign spillovers, no robust and significant short run effect is observed. But the long run effect of foreign trade comes out positive and significant, and is fairly robust across specifications. In the benchmark formulation the coefficient is significant at 10% level, and gives a long run elasticity (always measured at average historical values) of 0.19. This means that 1% increase in trade share of GDP implies 0.19% increase in agricultural productivity. During the period in question, 1975–96, annual average growth rate of trade/GDP was 3.3%. According to our estimate this should result in an annual increase in TFP of 0.63%, explaining more than 80% of the actual growth in TFP of 0.78% per year.

To test the robustness of this fairly strong foreign spillover effect in agriculture, alternative specifications are investigated. Excluding the LBD – variable, which turned out to be insignificant, gives a slightly smaller elasticity of foreign trade (0.14 versus 0.19), but the coefficient is strongly significant at 5% level. In an attempt to control for endogeneity we first give an extra lag to the trade variable. This changes the coefficient somewhat, and it also looses its significance. However, measuring openness with import tariffs, and in this way avoiding most of the endogeneity problem, gives a positive and significant long run effect of foreign spillovers on agricultural productivity, with a long run elasticity of tariffs of –0.21. In the mid 1970s tariffs in Thailand were about 12% of total imports. By 1996 this share was halved, implying an annual average decline of 3%. Hence, our model predicts an annual increase in agricultural productivity of 0.64%, which corresponds to the result with foreign trade as the measure of spillovers from abroad. The fit of this regression (equation 4) is described in Appendix C. Since both trade share of GDP and tariffs as share of imports are stationary variables in the long run, the effects above must be interpreted as a transitional. To investigate the dynamics, we estimate the effect of trade volume, as opposed to trade share, on productivity. As can be seen in the last two columns of Table 1, trade volume has no significant short or long run effect on productivity, and long run steady state effects are hence rejected.

To sum up, the estimates across alternative formulations offer a fairly consistent picture of a significant long run foreign spillover effect on agricultural productivity. It seems like the agricultural sector in Thailand has been able to take benefit of the potential learning and technological spillovers associated with an outward oriented economy.

Industry

In industry we separate between two channels for foreign spillovers. First, as in agriculture, trade share of GDP is used as a general measure of openness, representing

Table 2.
Determinants of Total Factor Productivity in industry

Dependent variable: $\Delta(A_M)_t = (A_M)_t - (A_M)_{t-1}$. Period: 1975–96.

	1	2	3	4	5	6
Constant	0.523*	0.522***	0.516***	0.550**	0.498***	0.540***
	(1.786)	(5.994)	(5.984)	(2.555)	(4.402)	(4.781)
$(A_M)_{t-1}$	-0.508**	-0.520***	-0.502***	-0.395***	-0.489***	-0.451***
	(-2.404)	(-5.002)	(-5.050)	(-3.196)	(-3.745)	(-4.404)
$\Delta(CU)_t$	1.038*	0.982**	1.095***	1.169***		1.104***
	(1.789)	(2.607)	(3.558)	(3.100)		(3.298)
$\Delta\,[(EX+IM)/Y]_t$	0.125	0.139				
	(0.440)	(0.630)				
$[(EX+IM)/Y]_{t-1}$	0.196	0.205$^{***1)}$				
	(0.743)	(2.562)				
$\Delta[(EX+IM)/Y]_{t-1}$			0.301		0.438	
			(1.276)		(1.431)	
$[(EX+IM)/Y]_{t-2}$			0.180$^{***1)}$		0.149$^{*1)}$	
			(2.297)		(1.454)	
$\Delta(FDI/I)_t$	1.399*	1.266**	1.193*	0.985	2.047**	
	(1.973)	(2.187)	(1.959)	(1.423)	(2.779)	
$(FDI/I)_{t-1}$	0.921	0.994$^{**1)}$	0.892$^{*1)}$	1.052$^{*1)}$	1.510$^{**1)}$	
	(1.686)	(1.940)	(1.663)	(1.630)	(2.262)	
$\Delta(L_M/L)_{t-1}$	0.149					
	(0.369)					
$(L_M/L)_{t-2}$	-0.028					
	(-0.052)					
$\Delta(tariff)_t$				-0.755		
				(-0.746)		
$(tariff)_{t-1}$				-0.732		
				(-0.912)		
$\Delta(EX+IM)_{t-1}$						0.0007
						(0.251)
$(EX+IM)_{t-2}$						0.0002
						(0.426)
$\Delta(FDI)_t$						0.0003
						(1.518)
$(FDI)_{t-1}$						0.0002$^{*1)}$
						(1.535)
R^2	0.79	0.78	0.78	0.70	0.59	0.75
DW	2.51	2.62	2.48	2.49	1.53	2.63

t – statistics in parenthesis. *** – The variable is significant at 1% level. ** – The variable is significant at 5% level.
* – The variable is significant at 10% level. 1) The significance relates to the long run solution.

spillover effects due to increased access to technologically sophisticated intermediate and capital goods, together with increased competition. A more open economy is more likely to take benefit of and learn from the world technological frontier. Second, foreign direct investments relative to gross capital formation are assumed to have a positive impact on industrial productivity. Foreign ownership and investments are associated with higher efficiency as an alternative source of foreign spillover.

Estimation results for determinants of industrial TFP are given in Table 2, with the benchmark formulation in the first column. We observe a positive and fairly robust long run relationship between TFP and both channels of foreign spillovers. FDI share also comes out with a significant short run effect on productivity. However, our econometric model faces some potential endogeneity problems, and especially the FDI share elasticity is sensitive to econometric specification. Within sector LBD is tested for, but as in agriculture no robust effect is detected. The short run effect of capacity utilization is positive and strongly significant in all specifications, indicating that industrial TFP is affected by business cycles.

The long run effect of trade share of GDP is significant at 5% level with an elasticity of 0.17. This means that around 30% of the actual annual increase in TFP of 1.81% comes from this foreign spillover channel. Giving an extra lag to the trade variable does not affect the magnitude or significance of the effect. When we use import tariffs as independent variable, the coefficient still has the expected sign and explains around 24% of the increase in productivity, but it is no longer significant. Spillovers from foreign direct investments have a significant long run effect on industrial productivity with an elasticity of 0.04. Being a flow variable, the FDI share varies a lot over time and has an average annual growth of 19.7% in the period 1975 – 96. According to our estimates the FDI share effect accounts for about 45% of observed TFP variation. Hence, in the benchmark formulation, the two foreign spillover channels together explain around 75% of the increase in industrial TFP. If we focus on Thailand's high growth period, 1987–95, the magnitude of the two effects predicts a somewhat higher average TFP growth than observed, and the spillover channel through trade is found to be relatively more important. Our preferred equation 3 is shown in Appendix C.

While trade share of GDP is fairly consistent across specifications explaining around 30% of the TFP variation over time, the elasticity of the FDI share effect is less robust. In the benchmark formulation the FDI spillover accounts for 45% of the actual increase in TFP, but if we do not correct for business cycle effects, this number raises to 80%. This might indicate a simultaneity problem between FDI share and capacity utilization, and future research should study this relationship closer.

As discussed above, the long run effects of foreign spillovers using the share variables represent transition effects. When the variables are represented as trade and FDI levels, the level effect of trade is not significant, but FDI comes out with a positive and significant (at 10% level) long run effect on industrial productivity. Higher FDI level brings with it higher productivity over time, which may reflect a steady state effect. The long run elasticity is of the same magnitude as for FDI share.

To further investigate the productivity dynamics and the possibility of endogenous growth rate effects, we suggest an alternative dynamic specification with productivity growth rate as dependent variable (using log-linear approximation):

$$\Delta(\ln(A_M))_t = a_0 + a_1 \ln(A_M)_{t-1} + a_2\Delta\left(\ln\left(\frac{EX+IM}{Y}\right)\right)_{t-1} + a_3\ln\left(\frac{EX+IM}{Y}\right)_{t-2} + a_4\Delta\left(\ln\left(\frac{FDI}{I}\right)\right)_t + a_5\ln\left(\frac{FDI}{I}\right)_{t-1} + a_6\Delta(\ln(CU))_t + (U_M)_t$$

where A_M is TFP level in industry, $\Delta(\ln(CU))$ is growth rate of industrial capacity utilization, and u_M is the error term. The estimates separate between temporary and permanent growth rate effects of the foreign spillover variables (trade/GDP and FDI/I). According to endogenous growth theory, higher trade or FDI shares should generate a permanent higher rate of productivity growth. This hypothesis can be tested in the regression above. If the coefficient of the lagged endogenous variable, a_1, is equal to zero, a significant effect of trade or FDI share implies long run growth rate effects. When a_1 is negative, higher trade or FDI share only has temporary effects on the productivity growth rate, and the hypothesis of long run endogenous growth rate effects can be rejected.

Estimation results for industry are given in Table 3. Since FDI is a flow variable with significant fluctuations over time, the log-linear approximation is rather inaccurate. While actual growth rate of FDI/I averages 19.7% per year for the period 1975–96, the log-linear approximation predicts an average annual growth of –2.4%. This might explain the insignificance of the variable, shown in the first column of Table 3. Due to this inaccuracy we run an alternative regression

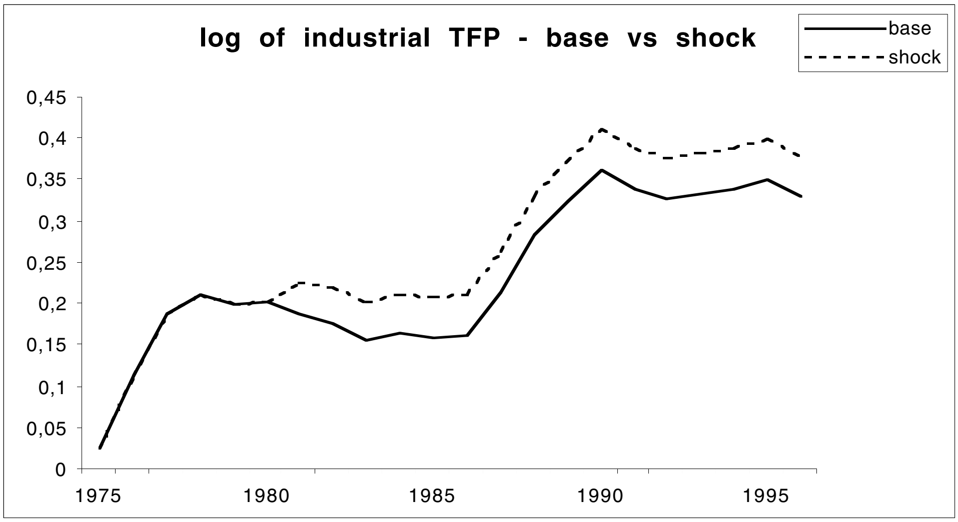
Table 3.
Test of productivity dynamics

Dependent variable: $\Delta(\ln(A_M))_t = \ln(A_M)_t - \ln(A_M)_{t-1}$. Period: 1975–96.

Constant	0.215***	0.167***
	(3.163)	(4.198)
$\ln(A_M)_{t-1}$	-0.523***	-0.462***
	(-5.161)	(-5.209)
$\Delta(\ln(CU))_t$	0.899***	0.991***
	(4.044)	(4.730)
$\Delta[\ln((EX+IM)/Y)]_{t-1}$	0.167	0.148
	(1.683)	(1.553)
$\ln[(EX+IM)/Y]_{t-2}$	0.102***1)	0.086***1)
	(2.649)	(2.412)
$\Delta[\ln(FDI/I)]_t$	0.014	
	(1.238)	
$\ln[FDI/I]_{t-1}$	0.007	
	(0.542)	
R^2	0.79	0.76
DW	2.44	2.67

t – statistics in parenthesis. *** – The variable is significant at 1% level. ** – The variable is significant at 5% level.
* – The variable is significant at 10% level. 1) The significance relates to the long run solution.

Figure 1.
Effects on log of industrial productivity of an increase in trade/GDP of 30%.

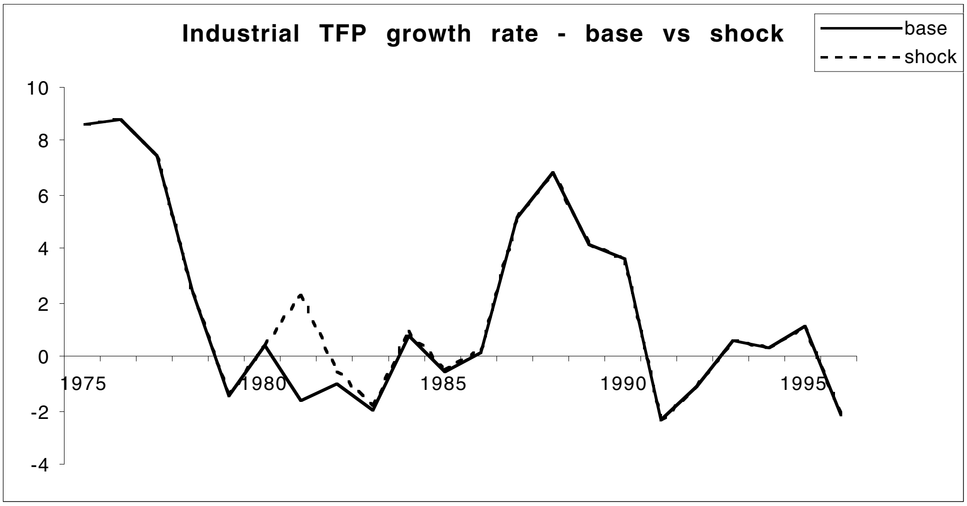


focusing on the relationship between productivity growth and trade/GDP level, given in the second column of Table 3. The short run effect of growth in trade/GDP on industrial productivity growth is positive and significant at 20% level with an elasticity of 0.15. Since the lagged endogenous variable is negative and significant, an increase in trade/GDP level only affects productivity level, and not growth rate, in the long run. The effect is significant at 5% level with an elasticity of 0.19. We also tried various specifications in agriculture with productivity growth as endogenous variable. The short and long run effects are both positive, but seldom significant. However, the lagged endogenous variable always comes out negative and significant, indicating that an increase in the level of trade/GDP only has temporary effects on productivity growth also in agriculture. These results are consistent with the productivity specification in the Nelson-Phelps model.

Based on the econometric specification in the second column of Table 3, we shock the model to study how the productivity dynamics work. We assume a 30% increase in trade/ GDP ratio in 1980, then returning to the same growth rate as before, but at a 30% higher level. Both short and long run effects are taken into account, and the impact on TFP level and growth rate is illustrated in Figures 1 and 2, respectively. An increase in the level of trade/GDP has a long run permanent effect on the productivity level, about 5% higher in 1996, but only a temporary effect on productivity growth rate. In other words, while the growth rate effect gradually disappears, it leaves a permanent higher level of productivity. To have a permanent effect on productivity growth rate, trade/GDP must grow in the long run, which is clearly implausible.

Our results are broadly consistent with cross-country evidence of a positive linkage between openness and TFP documented by

Figure 2.
Effects on industrial productivity growth rate of an increase in trade/GDP of 30%.



Edwards (1998), Coe et al. (1997), and Borensztein et al. (1998). Only a few country studies are made in this tradition. The most relevant is a study of aggregate TFP for Taiwan during 1951–1990 by Dessus (1999). The time series allows for a closer examination of the dynamics and in particular the speed of convergence to the world frontier (productivity level in the US). Dessus concludes that trade flows affect productivity in Taiwan and that imports of technology is the main channel.

Concluding remarks

The importance of total factor productivity for economic growth is now widely accepted. So far empirical contributions have mainly been cross – country studies, while we in this paper consider a single country, Thailand, and investigate the sources behind its productivity growth. Thailand has experienced an annual average growth of remarkable 6.6% during the period 1950–2000. It is our understanding that TFP growth in Thailand mainly have been driven by learning and imitation, while investment in own research and development has played a minor role.

We offer an econometric analysis of productivity sources in agriculture and industry for the period 1975–96. Our focus is on foreign spillovers, also allowing for within sector learning by doing. Foreign spillovers are assumed channeled through foreign trade and foreign direct investment (in industry). We observe a strong and fairly robust long-run relationship between openness and productivity in both domestic sectors and this is understood as an effect during transition growth with increasing trade share of GDP and foreign investment share of investment. The magnitude of this spillover effect is relatively equal across sectors, and hence both agriculture and industry are able to take benefit of and learn from technology improvements abroad. 1% increase in the trade/ GDP ratio is shown to give about 0.17–0.19% increase in domestic productivity levels. Since annual average growth in trade/GDP has been about 3.3 % during 1975–96, this foreign spillover channel explains more than 80% of the TFP growth in agriculture and about 30% of the growth in industry. Together with the FDI effect our model explains around 75% of industrial TFP growth during 1975–96.

The dynamics of the effects are investigated in alternative specifications. When the spillover variables are estimated on level form, long run effects of FDI are identified, while trade is found to have significance only as transition effect. A separate test of endogenous growth rejects long run growth rate effects of the sources of spillover. By introducing an exogenous shock to the model, we illustrate how an increase in the trade/GDP level only affects the level of productivity in the long run, while it has a transitory effect on productivity growth rate.

Other empirical studies, like Tinakorn and Sussangkarn (1998), Uruta and Yokota (1994), and Stokke (2000), show that the openness of the economy has improved productivity in Thailand. All these analyses, and the present one included, certainly face some econometric challenges, especially because of possible endogeneity problems, but it seems like foreign spillovers have been one of the major determinants of productivity growth in Thailand.

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Appendix A: Data description and sources

Variable	Definition	Source
X_i	Sectoral gross domestic product in constant 1988 prices.	National & Social Economic Development Board (NESDB): National Income Accounts of Thailand 1970-1990, table 3 ("Gross National Product at 1972 prices by Industrial Origin"), and National Income Accounts of Thailand 1980-1996, table 3 ("Gross National Product at 1988 prices by Industrial Origin"). The two sub-periods are combined by using the GDP deflator for Thailand given in World Development Indicators, 2001, CD-ROM version (base-year 1988).
K_i	Sectoral gross capital stock in constant 1988 prices.	NESDB (www.nesdb.go.th), The National Balance Sheet Section of the Economic Analysis and Projection Division.
L_i	Sectoral labor use (number of persons).	LABORSTA, International Labour office database on labour statistics operated by the International Labour Organization (ILO) Bureau of Statistics (www.ilo.org), Table 2B ("Total employment by economic activity").
LD	Land use, arable land as percent of land area.	The World Bank, World Development Indicators, 2001, CD-ROM version.
(EX+IM)/Y	Total exports and imports relative to aggregate GDP (constant US $).	The World Bank, World Development Indicators, 2001, CD-ROM version.
EX+IM	Total exports and imports in constant 1995 US $.	The World Bank, World Development Indicators, 2001, CD-ROM version.
FDI/I	Foreign direct investments (net inflows) as share of gross capital formation (constant US $).	The World Bank, World Development Indicators, 2001, CD-ROM version.
FDI	Foreign direct investment (net inflows) in constant US $.	The World Bank, World Development Report, 2001, calculated based on FDI/GDP-ratio and GDP in constant US $.
Tariff	Import duties as share of total imports.	Import duties in current prices (baht) from Government Finance Statistics Yearbook (Account 6.1, yearbooks from 1980, 1985, 1990 and 1999). Total imports in current prices (baht) from National Income Accounts of Thailand 1970-1990 and 1980-1996 (NESDB), table 1 ("Balance Sheet of National Income and Expenditure at Current Market Prices").
CU	Capacity utilization in industry.	GDP trend calculated based on average growth rate, capacity utilization defined as actual GDP relative to trend.

Appendix B: Econometric specification

The benchmark formulation in industry and agriculture, respectively, is given as:

$$\Delta A_{M,t} = a_0 + a_1 A_{M,t-1} + a_2 \Delta \left(\frac{EX + IM}{Y}\right)_t + a_3 \left(\frac{EX + IM}{Y}\right)_{t-1} + a_4 \Delta \left(\frac{FDI}{I}\right)_t + a_5 \left(\frac{FDI}{I}\right)_{t-1}$$

$$+ a_6 \Delta \left(\frac{L_M}{L}\right)_t + a_7 \left(\frac{L_M}{L}\right)_{t-1} + a_8 \Delta CU_t + u_{M,t}$$

$$\Delta A_{A,t} = b_0 + b_1 A_{A,t-1} + b_2 \Delta \left(\frac{EX + IM}{Y}\right)_t + b_3 \left(\frac{EX + IM}{Y}\right)_{t-1} + b_4 \Delta \left(\frac{L_A}{L}\right)_t + b_5 \left(\frac{L_A}{L}\right)_{t-1} + u_{A,t}$$

where $\Delta A_{i,t} = A_{i,t} - A_{i,t-1}$, $\left(\frac{L_i}{L}\right)$ is sectoral labor share and $u_{i,t}$ is the error term, $i = A, M$. $\left(\frac{EX + IM}{Y}\right)$ is the sum of total export and import as share of aggregate GDP, ΔCU is change in industrial capacity utilization, while $\left(\frac{FDI}{I}\right)$ is foreign direct investments relative to gross capital formation. The coefficients a_6 and b_4 is understood as the short run effect of internal LBD in industry and agriculture, respectively. The short run effect of openness is represented by a_2 and b_2, while a_4 measures the short run effect of foreign direct investments in industry. Correction for business cycles in industry is captured by the coefficient a_8. The long run effects take into account the dynamics of the lagged dependent variable, and are measured by $-a_7/a_1$ and $-b_5/b_1$ for LBD, and $-a_3/a_1$ and $-b_3/b_1$ for foreign spillovers through trade, in industry and agriculture, respectively. The effect of foreign direct investments on industrial productivity is in the long run represented by the coefficient $-a_5/a_1$.

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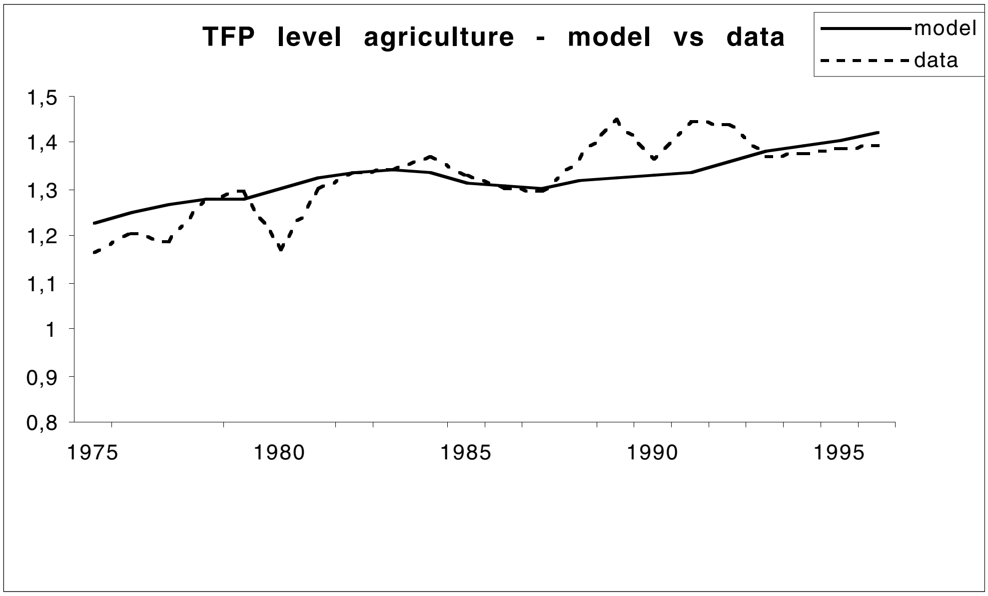
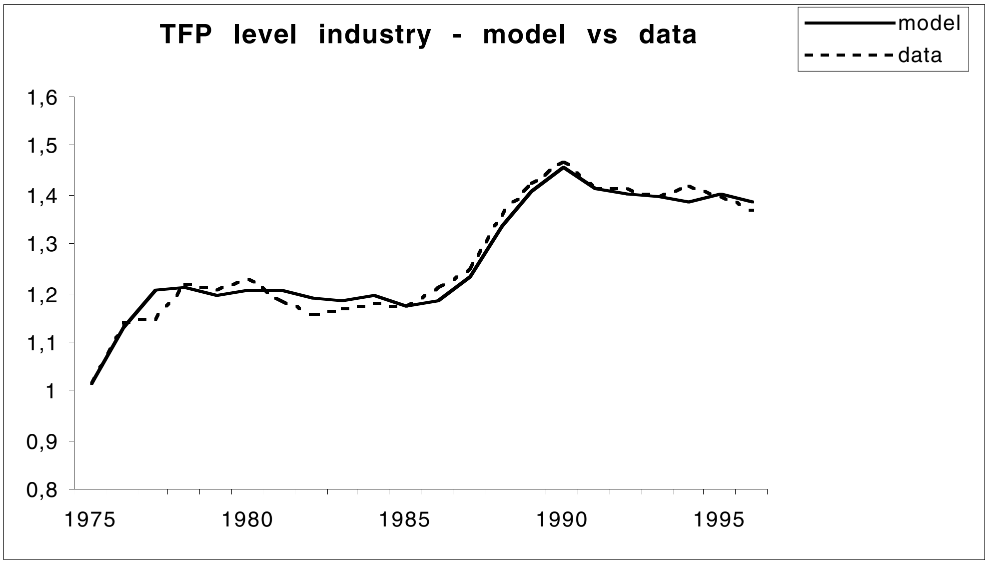
Appendix C: Secoral TFP level based on econometric modeling





Appendix D:
Average values (1975–96) of model variables used in elasticity calculations

Variable	Average value
$\Delta(A_A)$	0.009
A_A	1.329
$\Delta(A_M)$	0.020
A_M	1.272
$\Delta[\ln(A_M)]$	0.017
$\ln(A_M)$	0.236
$\Delta(L_A/L)$	-0.004
L_A/L	0.633
$\Delta(L_M/L)$	0.004
L_M/L	0.367
Δ[(EX+IM)/Y]	0.018
(EX+IM)/Y	0.576
Δ(EX+IM)	6.044
EX+IM	57.12
Δ[ln((EX+IM)/Y)]	0.030
ln[(EX+IM)/Y]	-0.591
Δ(tariff)	-0.003
tariff	0.097
Δ(CU)	0.003
Δ[ln(CU)]	0.003
Δ(FDI/I)	-0.001
FDI/I	0.030
Δ(FDI)	8.242
FDI	110.0
Δ[ln(FDI/I)]	-0.024
ln(FDI/I)	-3.69