



รายงานวิจัยฉบับสมบูรณ์

โครงการ การเพิ่มทุนมนุษย์กับการเจริญเติบโตทางเศรษฐกิจใน
ประเทศไทย

โดย

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สนับสนุนโดยสำนักงานกองทุนสนับสนุนการวิจัย

(ความเห็นในรายงานนี้เป็นของผู้วิจัย สกว.ไม่จำเป็นต้องเห็นด้วยเสมอไป)

กิตติกรรมประกาศ

งานวิจัยสำเร็จลงได้ด้วยความช่วยเหลือจากหลายฝ่าย ผู้เขียนขอขอบคุณสำนักงานกองทุนสนับสนุนการวิจัย ที่กรุณาให้การสนับสนุนทุนวิจัย และเวลาอย่างเต็มที่สำหรับการวิจัย ผู้เขียนต้องขอขอบพระคุณศาสตราจารย์ ดร. อภิชัย พันธเสน ที่กรุณารับเป็นพี่เลี้ยงการวิจัยและให้คำแนะนำที่เป็นประโยชน์ ศาสตราจารย์ Ian Coxhead มหาวิทยาลัยวิสคอนซิน-แมดิสัน สหรัฐอเมริกา ที่กรุณาให้คำแนะนำในการแก้ไขบทความ นอกจากนี้ ต้องขอขอบคุณรองศาสตราจารย์ ดร. วิมุต วาณิชเจริญธรรม มหาวิทยาลัยหอการค้าไทย ที่ให้ความช่วยเหลือในด้านข้อมูลที่จำเป็นในการวิจัย ผู้ช่วยวิจัยอีกหลายท่าน ได้แก่ คุณ กรณ์รัตน์ นาขวา ที่ได้ช่วยเหลือการเก็บข้อมูล และทำงานได้เป็นอย่างดี

ความคิดเห็นและข้อผิดพลาดในรายงานฉบับนี้เป็นของผู้เขียนแต่ผู้เดียว

ชัยยุทธ ปัญญสวัสดิ์สุทธิ์

Abstract

Project Code : PDF / 58 / 2543

Project Title : Human Capital and Economic Growth in Thailand

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Project Period : 2543-2545

This research contains three essays. The first essay summarizes the roles and the channels through which human capital contributes to economic growth. We discuss relationships between human capital and growth both theoretically and empirically. The second essay reviews the measurements of human capital suggested in literature and provides new estimated stocks of human capital in Thailand during 1985-2005. The third essay provides empirical evidences supporting the role of externality in human capital accumulation to economic growth in Thailand, and presents a simple general equilibrium model to capture the relationship between human capital and economic growth for the Thai economy.

Keywords : human capital, economic growth, schooling, education, externality

บทคัดย่อ

รหัสโครงการ : PDF / 58 / 2543

ชื่อโครงการ : การเพิ่มทุนมนุษย์กับการเจริญเติบโตทางเศรษฐกิจ

ชื่อนักวิจัย : รศ. ดร. ชัยยุทธ ปัญญาสวัสดิ์สุทธิ์

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ระยะเวลาโครงการ 2543-2545

งานวิจัยฉบับนี้มี 3 ส่วน ส่วนแรกเสนอผลการศึกษาทบทวนวรรณกรรมปริทัศน์ความสัมพันธ์ระหว่างทุนมนุษย์กับการเจริญเติบโตทางเศรษฐกิจในระยะยาว ตามแนวคิดของทฤษฎีการเจริญเติบโตทางเศรษฐกิจแนวใหม่ (New Growth theory or Endogenous Growth Theory) ส่วนที่สอง เสนอผลการประมาณการสต็อกของทุนมนุษย์ในประเทศไทยในช่วงค.ศ. 1980-2005 ที่มี ความเหมาะสมและเป็นประโยชน์ต่อการวิเคราะห์การเจริญเติบโตทางเศรษฐกิจ ผลที่ได้ให้นำไปใช้ ในแบบจำลองที่พัฒนาในส่วนถัดไป ส่วนที่สาม เสนอการวัดผลกระทบภายนอกที่เกิดจากการสะสม ทุนมนุษย์ และแบบจำลองทางคณิตศาสตร์เพื่อใช้ในการประมาณค่าผลกระทบของการสะสมทุน มนุษย์ต่อการเติบโตทางเศรษฐกิจ รวมทั้งผลการทำซิมูเลชันที่เกิดจากการเปลี่ยนแปลงปัจจัยที่มีผล ต่อการสะสมทุนมนุษย์ อันได้แก่ นโยบายการค้าระหว่างประเทศ และระดับของผลกระทบภายนอกจากการสะสมทุนมนุษย์

คำหลัก ทุนมนุษย์ การเติบโตทางเศรษฐกิจ การศึกษา ผลกระทบภายนอก

สรุปผลลัพธ์จากโครงการ
โครงการ การเพิ่มทุนมนุษย์กับการเจริญเติบโตทางเศรษฐกิจในประเทศไทย

1. ผลงานตีพิมพ์ในวารสารวิชาการนานาชาติ
ยังไม่มี แต่อยู่ระหว่างการดำเนินการ
2. การนำผลงานวิจัยไปใช้ประโยชน์
 - เชิงวิชาการ
 - ใช้ในการพัฒนาการเรียนการสอนวิชาเศรษฐศาสตร์การพัฒนา ระดับปริญญาโท และปริญญาเอก ของคณะเศรษฐศาสตร์ มหาวิทยาลัยธรรมศาสตร์ ที่สอนเป็นภาษาอังกฤษ
 - มีการทำวิจัยในหัวข้อที่เกี่ยวข้อง ในรูปวิทยานิพนธ์ระดับมหาบัณฑิต และดุษฎีบัณฑิต หลายเรื่อง
 - สามารถนำไปใช้ในการวิจัยต่อในอีกหลายสาขา ที่ต้องอาศัยข้อมูลทุนมนุษย์ที่อยู่ในรูปของหน่วยเงินตรา อาทิ การวัดผลผลิตภาพการผลิตของประเทศ การประมาณการสมการผลผลิตของระบบเศรษฐกิจ
 -
3. ผลงานอื่นๆ
 - จะนำเสนอในการประชุมวิชาการ
 - ระหว่างส่งเพื่อพิจารณาในวารสารวิชาการในประเทศ อาทิ Thammasat Review หรือวารสารเศรษฐศาสตร์ธรรมศาสตร์

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Human Capital and Economic Growth: A Review Essay^{*}

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Abstract

It is still inclusive to specify the relationship between human capital and output growth as implied by the Neoclassical framework or the Nelson-Phelps approach. The Neoclassical framework implies that current investment leads to a one-time surge in output as new human capital is applied in production. In contrast, the Nelson-Phelps framework implies that current investment, by raising the level of human capital, has a permanent effect on technical change and hence growth. It is interesting to explore further the model in which educational attainment and technology are complement. The model developed along this line is still in its infancy. Therefore, research along this line is promising.

JEL Classification Codes; J24, O40, H23

Keywords: Human capital, economic growth, externalities

^{*} The author would like to thank the Thailand Research Fund Foundation for research grant. The author have received helpful comments from Apichai Puntasen, Ian Coxhead, and a referee. E-mail address: chaiyuth@econ.tu.ac.th.

1.Introduction

The search for the engine of growth was among one of popular researches in the 1950s, but quickly died of in 1960s. Following Lucas (1988) and Romer (1988, 1990), the recent interest in growth economics since the 1980s has shift research effort away from the real business cycle theory that has dominated the field in the 1970s. The reason behind is recognition that for a small change on the long-term growth rate, we can contribute more to improvements in living standards than by analyses of countercyclical policy and fine-tuning.

The reemergence of the growth theory in the late 1980s is dubbed the new growth theory or endogenous growth theory, as opposed to the Neoclassical growth theory or exogenous growth theory. Overall, the new growth theories emphasize the roles of human capital and technology in explaining the divergence of economic growth among countries. By definition, human capital is embodied skill and knowledge, and since advances in technical knowledge drive economic growth, human capital accumulation and economic growth are then intimately related.

This paper reviews recent developments in growth economics, so called endogenous growth theory. Understanding these new theories helps broaden our ideas toward important issues debated in literature. The role of human capital on economic growth is emphasized and reviewed in greater details. However, this survey of theory is not meant to be exhaustive, but it serves as a template for understanding the major empirical issues in growth economics. For extensive theoretical survey of literature on growth, see Barro and Sala-i-Martin (1995) and Aghion and Howitt (1998).

This paper is organized as follows. In Section 2 we begin with the neoclassical growth model and discuss its limitations empirically and theoretically. Then we explore recent models of endogenous growth. Section 3 reviews in details the growth model based on the human capital in particular. Section 4 reviews the state of evidence on the role of human capital on economic growth. Section 5 gives concluding remarks.

2. Literature Review on Growth Economics

2.1 Neoclassical growth theory: An Assessment

The Neoclassical growth theory suggests that history does not matter in the long run. Countries with similar factor (capital and access to technology) may show temporary differences in growth rates (reflecting different initial conditions), but should not exhibit persistent differences. The convergence of per capita wealth irrespective of starting conditions operates through the adjustment of interest rates. As economies become richer, returns to capital decline along with the marginal product of capital, thereby reducing incentives to invest. Growth then slows down and vanishes.

However, international evidence on growth rates of per capita income reveals that striking inequalities persist in the development patterns of nations. Some countries are able to sustain high growth rates over long periods of time, while still others stagnate in low-growth rates or relatively low levels of income. These empirical facts suggest that the Neoclassical growth theory are not good at explaining why many poor countries cannot catch up. In other words, empirical evidences tend to show that history may matter for economic growth, including the government policies.

We begin with Solow growth model and then review its limitations at both theoretical and empirical levels. Then we explore recent development in new growth theory.

Solow's growth model can be illustrated with a simple aggregation production function that assumes neutral disembodies technology:

$$Y_t = A_t F(K_t, L_t)$$

when Y is total output, $F(.)$ is a constant return to scale production function, K is the capital stock, L is the labour force, and A is parameter representing Hicks-neutral technological change (no change in the ratio of the marginal product of capital to labour is allowed). The production technology exhibits diminishing returns to capital and labour. Population and labour growth are exogenous to the model, as is disembodies technology.

Under these assumptions, the model gives rise to a balanced growth path in which per capita capital is accumulated at the same rate as per capita output and per capita consumption. The saving rate and the real interest rate are constant along the equilibrium

path. The growth rate per capita output and consumption is strictly proportional to the given rate of technological progress. Thus, technological progress is the only source of growth. In equilibrium, the factor affecting the marginal propensity to save will affect only the level but not the growth rate of the per capita income in the long run. In other words, a thrifty society will end up wealthier than an impatient one, but it will not grow faster in the long run.

As pointed out by Lucas, the contribution of the simple neoclassical model to our thinking about economic growth is to "emphasize a distinction between 'growth effects' -- change in parameters that alter growth rates along balanced growth path-- and "level effects"--changes that raise or lower balanced growth path without affecting their slope-- that is fundamental in thinking about policy changes. Solow's (1956) conclusion that changes in saving rates are level effects..."(Lucas 1988, p. 12). The neoclassical contributions thus stem from its ability to quantify the effects of various influences on growth.

Since the work of Solow (1956) and Dennison (1961), it has been known that technological change accounts for a significant portion of GNP growth in industrialized countries. Also there is a fairly stable capital- output ratio in advanced nations. These facts have been well known for a long time and are in fact at the heart of Solow conclusion that technological change, not capital accumulation, is the source of most growth. Technological change has been measured either by estimating the time trend in regression of aggregate outputs on inputs or by indices of total factor productivity (TFP). Under both methods, productivity is measured as a residual: it incorporates all factors that influence GNP growth other than the increase in measured inputs. Using the growth accounting techniques describes by Solow¹, Chenery (1983) found that for the period 1960-1973 most developed countries can attribute more than half their growth rate to technical change or growth in total factor productivity (TFP). However, the contribution of TFP was less than a quarter of the

¹ To measure the Solow residual or TFPG, we start from the basis production function: $Y = f(K, L)$. By differentiating and applying Euler's theorem to this function, we can derive: $TFPG = \frac{\dot{Y}}{Y} - (1 - a_L) \frac{\dot{K}}{K} - a_L \frac{\dot{L}}{L}$, where a_L is share of labour out of total income and dot means time derivative.

growth rate for middle-income developing countries². Despite various refinements to the measurement of total factor productivity, there is still no convincing explanation for its source. (See Jorgenson and Grilliches 1967)

Furthermore, the Solow / neoclassical growth model implies that, even if the process of convergence of steady- state growth rate is relatively low, it should ultimately occur across countries. Several decades of economic data should be sufficient to detect convergence. Other things being equal, countries that begin with relatively low capital and low income should initially grow faster. This convergence hypothesis is sometimes tested by plotting the logarithm of real per capita output versus the mean annual growth rate. Contrary to the convergence hypothesis, empirical studies found no tendency for a low initial level of income to be associated with high growth even over the subsequent period. Baumol (1986) argued that there is a tendency toward convergence in the level of productivity within groups of advanced countries, but not for all countries. His result was later criticized since his grouping is somewhat biased by choosing *ex post* characteristics of countries for his sample. In contrast, Delong (1988) found evidence of persistent variance in economic growth rates, even across industrialize countries, over the period 1870-1979, and fluctuations in trends of productivity growth within individual economies over the same period.

Moreover, the model predicts that the observed rates of growth would differ mainly by transition dynamics. Theoretically, a wide variety of dynamic paths for output growth may arise by virtue of transitory differences in capital stock that are initially lower than their balanced growth path. King and Rebelo (1993) found that the observed diversity in levels and rates of economic growth over time and across countries could not be explained by transitional dynamics of the neoclassical model of capital accumulation. They found extremely counterfactual results from simulation based on the Neoclassical model. These findings are often taken to be a strong refutation of the neoclassical growth model. The idea that steady-state growth rates may not converge over the long run, thus, has been the driving impetus in proliferating literature on endogenous growth theory.

² The outlier in this study, where its growth rate were over 10 percent on average, were Japan, Israel, Spain, Hong Kong, Taiwan and South Korea with approximately half of the growth associated with increased TFP and half of growth associated with increased TFP and half with factors accumulation.

Regarding the relationship between economic policy and growth, the most serious problem of traditional growth theory is that the steady-state of per capita output growth does not depend on policy parameters in equilibrium. This means that two identical countries will grow at the same rate if they differ from each other only in terms of policy parameters. The successful stories of Taiwan, Hong Kong and Singapore tell us different stories about the role of state intervention and industrial policy in promoting economic growth.

Therefore, under the assumptions of constant returns to scale, the diminishing marginal product of capital, and exogenous technological change, the Solow-type model and its variants leave us with the conclusion that we do not understand why countries grow, or why some grow faster than others.

New Growth theory: What is new?

It was Paul Romer (1986,1990) and Robert Lucas (1988) who created the new wave of growth theory. Romer argued that the constancy of the capital-output ratio is in fact strong evidence that returns to scale are not constant. Thus one need not invoke exogenous technological change to explain sustained growth. “By assigning so great a role to ‘technology’ as a source of growth, the theory is obliged to assign correspondingly minor roles to everything else, and so has very little ability to account for the wide diversity in growth rates that we observe” (Lucas, 1988, p. 15)

By allowing variations across countries in technology in both level and rate of change, it provided a new ability to account for wide differences in income levels and growth rates. This realization does in fact accord with everyday observations. Lucas pointed out that differences in “technology” across countries are indeed a differences in knowledge of people, or difference in Human capital”. What we need then is a formal model that leads us to think about individual decisions to acquire knowledge or invest in human capital, and about the consequences of these decisions for productivity. Later research has thus focused on the process of accumulation of knowledge capital. Two themes of the determinants of long-run growth are based on investments in human capital and investments in R&D to create new technologies.

Human Capital Accumulation: Romer (1986), Lucas (1988)

This model emphasizes the roles of externality and increasing return of investment in human capital. Maintained assumption in this model is that new goods do not matter in the aggregate economy. The argument is based on three premises. First, knowledge is assumed to be inputs in production and has an increasing marginal product. Second, there are spillover effects from investment in knowledge among firms. Third, the production of new knowledge exhibits decreasing returns. With these three elements, the marginal product of capital need not decline over time to the level of the discount rate. Then the incentive to accumulate capital can persist indefinitely, and long-run growth in per capita income can be sustained.

This view can be represented by Lucas's model, which suggested the explicit introduction of human capital accumulation into the standard constant-returns-to-scale production function:

$$Y = K^{\beta} L^{1-\beta}, \text{ and } L = \mu hn$$

where Y output, K physical capital, L effective labor force, μ fraction of time spent in production, n population growth, h human capital per worker, and β capital share.

Human capital per worker is assumed to be a linear function of time spent in school and quality of education:

$$\frac{\dot{H}}{H} = d(1 - \mu)$$

where d denotes the quality of the education system.

The optimal allocation of this competitive equilibrium can be solved using the standard Hamiltonian framework for the equivalent social planner problem. In this model, the balanced growth path of per capita output, consumption, and physical capital depends on the intertemporal elasticity of substitution in consumption, the quality of the educational system that reflects the human capital accumulation, and the time discount rate. Along this path, growth increases with the effectiveness of investment in human capital, with a high intertemporal elasticity of substitution (more willingness to defer consumption to the future), and declines with increases in the discount rate (less patience). Under this model, the

implication is that a thrifty economy will end with a higher level of income per capita and a higher growth rate, and that an economy beginning with low levels of human capital and physical capital will remain permanently below an initially better endowed economy.

Endogenous Innovation: Romer (1990), Grossman and Helpman (1990, 1991):

This view focuses on the commercially oriented innovation efforts that respond to economic incentives as a major engine of technological progress and economic growth. Neo-Schumpeterian models of growth proposed by Aghion and Howitt (1990, 1998), and Grossman and Helpman (1991) motivate recent advances in growth theory. These models explicitly allow for the introduction into an economy of new or improved types of goods. Unlike the previous new growth models, new goods do matter at the aggregate level in this model. The possibilities for the introduction of the neo-Schumpeterian models are that every economy faces virtually unlimited possibilities for the introduction of new goods, and that firms undertake innovation based on expected monopoly profits. Advanced countries can discover new goods. Developing countries can import them. These new goods can be tangible or intangible. Without fundamental change in the underlying economic analysis, new goods can be modeled as inputs in production (Romer 1990), or as consumption goods (Grossman and Helpman 1990, 1991).

In Romer (1990) knowledge capital is the key (public) input to the research sector, which generates the new products or ideas that underlie technological progress. Research successes generate some degree of market power, and so create monopoly profit opportunities. These potential profits justify the expenditure on R&D. Thus countries with a greater initial stock of knowledge capital will experience a more rapid rate of introduction of new goods and therefore tend to grow faster. In addition, a larger stock of knowledge capital makes it easier for a country to absorb the new product or ideas that have been discovered elsewhere. Hence, a follower country with more knowledge capital tends to grow faster because it catches up more rapidly to the technology leader.

In Grossman and Helpman (1990), expenditure on R&D generate three forms of technological progress: cost reduction of existing products (process innovation), inventing entirely new products (product innovation), or quality improvement. For product innovation, they assume that an amount of R&D is required to develop a new differentiated product

before it can be produced. In this sense, R&D is an ordinary investment activity generating new blueprints for new products. Producers of unique products earn monopoly rents, which serve as the reward for their R&D expenditure. For product quality improvement, R&D are justified by profit opportunities. Producers of state-of-art-products can earn positive profits in their competition with manufactures of lesser quality goods. For both form of technological progress, innovative products can be either consumer goods or intermediate goods. For the latter, innovation enhances total factor productivity for the sector producing that final goods, and thereby growth in the standard way. Under free entry situation, an equilibrium return to innovation in R&D sector is determined by an opportunity cost of capital and risk premium.

In all above model, there are fixed costs associated with the introduction of each new good. The endogenous innovation model takes into account the fixed cost that limits the set of goods. In contrast to the traditional trade theory where the existence of fixed costs justify government intervention, including trade restriction and Infant industry argument, this model argues unequivocally for free trade.

For these models, international trade and trade policy can affect a country's growth if it affects the incentive to engage in R&D in that country. We explore its possible channels. First, trade barriers that increase that cost of R&D in general equilibrium influence profit rate and thus dampen growth of the country that generates innovation. Second, openness to international trade induces foreign competitors and may reduce expected profits of home producers. In contrary, openness to international market increases market size and provides greater opportunities for the exploitation of R&D benefits. Therefore, it is comparative advantage that determines which countries will specialize in the creation of knowledge and in production of human-capital intensive products. Third, if there are spillovers in the process of knowledge generation, these spillovers will cause aggregate investment in knowledge to exhibit increasing returns to scale and, therefore, allow innovation and growth to be a sustainable process in the long run. Forth, an increase in the supply of the resource used intensively in the knowledge-generating sector speeds growth (Rybczynski theorem). Thus, trade policies that shift resources into the knowledge-generating sector speed rate of growth. For example, protection such sector will increase demand for outputs generated by such

sector and thus expected return to R&D investment. Similarly, protection of the sector that competes with inputs used in the R&D sector will decrease growth. Fifth, in the product life cycle model both countries can capture spillovers benefits generated by trade. Product imitation raises incentive to innovate, since the country innovating new product will earn greater profit through trade. Such trade speeds growth in both countries. Thus the policy that protects intellectual property right will increase growth in foreign country.

Studies of the exact form that the spillovers can take are rare in the current literature. Grossman and Helpman hypothesized that local knowledge capital is likely to vary positively with the extent of contact between domestic agents and their counterparts in the international R&D and business communities, and that the number of such contacts increases with the level of commercial exchange. In other words, commodity trading serves as a conduit for information flows. It is obvious that in real business, not all-commercial interactions can generate improvement in the stock of knowledge of capital, and that international spillovers are not instantaneous. Moreover, the exact form in which the spillovers take place may vary in different applications and for different type of industrial research. In conclusion, we still are far from understanding this question. To answer this question, new empirical research, in my opinion, should be devoted to understand the relationship between R&D and total factor productivity at the industry levels.

In brief, the emerging new theme emphasizes the importance of inventive activities for long-run growth on the one hand and role of economic incentives affecting in these activities on the other. It supports the idea that international trade can serve as a transmission mechanism since spillover of literature, this theory is still far from being supported by empirical evidence. Nevertheless many economists view that this endogenous human capital and innovation may help us to understand the connection between trade policy regimes and long-run growth (Lucas 1988, Grossman and Helpman 1990, Edwards 1993, Dollars 1993)

To this point, we have reviewed many variations on the new growth theory, and thereby explore the ways in which the trade policy regime can affect a country's growth. We have seen that the new growth models differ in the identification of engine of the growth and its mechanics, as well as the driving forces of accumulation. Before closing section, we try to sum up some common feature among these new models.

First All the endogenous growth models shift the emphasis from exogenous technological change to human capital accumulation as the key source of growth and development, which was pointed out much earlier by Schultz (1961). The growth catalyst is knowledge in either embodied human capital, as in Lucas, or in disembodied technological innovation forms, as in Romer. However, innovation as a result of R&D is presumably influenced by the human capital endowment.

Second A common result is the existence of diversity in growth levels or per capita income levels among different countries. In the Neoclassical growth model, the initial endowment of physical capital has no effect on the steady-state capital-labor ratio. Given similar levels of technological and preference parameters across countries, their long-run growth level would be expected to converge to a constant value. In contrast, endogenous growth theory implies that the initial stocks of physical and human capital will affect per capita income levels. This gives an explanation for the persistent diversity in income levels across countries.

Third The endogenous growth models allow for diversity in growth rates. Equilibrium growth rate can be affected by human capital endowment, which is exogenously determined, in Romer's model. In Lucas's model, the balanced growth path is affected by the index of human capital, a discount rate of time preference, and the intertemporal elasticity of substitution in consumption between periods.

Fourth Technological progress is the outcome of firms' decision, toward expected profits. It is market forces that generate technological innovation rather than non-profit scientific discoveries. In Romer's and Grossman and Helpman' models, growth is sustainable whenever the rate of return to innovation activity is commensurate with the rate of return to investment in physical capital in a steady state of balanced growth.

Toward Understanding Growth in Developing Countries: Some Critiques

There is no doubt that new developments in the new growth theory will help answer the question raised in this paper. Before making some comment relating to some aspects of developing countries, we first take lessons from the stock of previous studies before the popularity of the new growth theory.

Before the emergence of the new growth theory, there are a number of reasons why difference in trade orientation can affect growth both in the short and the long run. First, outward orientation makes it possible to use external capital for development without facing problems in servicing the corresponding debt. Distortion and variability in real exchange rate that is unsustainable is then negatively associated with growth. Second, outward orientation gives rise to export growth and there may exist externalities associated with exporting. The economy with export growth thus can grow more rapidly over a period of time. Empirical evidences indicating the positive relationship between exports and growths in total factor productivity support this view.

There are abundant examples in the literature investigating the relation between policy orientation, exports and output growth. An excellent literature survey on this issue can be found in Edwards (1993). According to Edwards, there are two broad categories of empirical work on this issue. The first is multi-country studies based on details of each country relating trade regimes and economic performance. The second has focused on the relationship between exports and output growth. There are, however, shortcomings to the latter analysis. The measurement of trade orientation is problematic.

In summary, the statistical and conceptual shortcomings in cross-country regression studies limit what we can learn from theory about policy and growth. However, suggestive empirical regularities from these analyses help strengthen our belief about policy and economic performance, for example, that trade liberalization helps growth and that financial development is associated with long-run growth. (Dollars 1993, and Levine and Zervos 1993).

Some Criticisms

(1) The central thesis of innovation-driven growth theory lies in explaining the growth of total factor productivity, which is the component of the output that is not attributable to the accumulation of inputs. The novelty of the new theory suggests that a country's TFPG depend not only on its own R&D capital stock, but also those of its trade partners.

In fact, the source of productivity change at the aggregate level has been the subject of detailed analyses much earlier. Previous studies indicated that the growth in industrialized

countries, while structural change and capital accumulation are more important in the process of growth in less developed countries (Stern 1989, p. 627). If this is the case, it implied that the R&D capital stock plays an insignificant role in explaining growth in developing countries. However this implication does not disprove the validity of new theory, but leads us to think about the reason why poor countries do not reap the benefits of technological advance as predicted by the theory.

(2) If endogenous technology is viewed as a means to achieve faster and sustained growth, it is essential to understand how new technologies are adapted in practice and why not if they are not adopted. For developing countries, we should emphasize the implementation of available technology rather than the creation of new technology for both agricultural and manufacturing sectors. For agriculture, we have to understand the constraints, and incentives to technology adoption that can be affected by economics policy and political environment. For example, past studies of the green revolution tell us that the adoption of higher yielding varieties requires more capital-intensity than previous one. The scarcity of capital has therefore controlled the pace of their implementation (Mundlak, 1993). Furthermore, policies that affect incentives will affect resource flow, thereby certainly affecting growth since the corrected incentives will result in increase efficiency in resource allocation: resources can flow to higher-return activities.

For the manufacturing sector, the appearance of the new technology in developing countries is often taken from development in advanced countries. However, specific knowledge is required in order to implement the new techniques. Besides general training, specific training and learning by doing is important in utilizing the new technology. Firms may have less incentive to provide specific training when facing an unskilled labour market. Shortage of skilled labour then can impede growth. The implementation of government policy is to support education system that will improve the human capital of the labour force. It is the productivity-differentials that will provide the corrected incentive in resources

allocation. This fact is an important issue for the new ASEAN NICs, since it has been argued that the human capital in these new NICs is lower than that of the old NICs.

(3) Sustained growth and innovation is possible through spillover effect of knowledge capital under the endogenous innovation theory. For developing countries, realization of this progress may be limited by constraints in information flows. Most of the time it is not costless and not continuously flows. Other information may be complementary to investment decision such as agriculture price or inputs prices. Poor communication, poor information or imperfect information may thus influence entrepreneurs' decision in investment or adopting new technology. Imperfect capital market also increases non-diversification risk.

(4) Most developing countries are notorious for rent-seeking activities. Easy corruption, uncertain property right, poor enforcement of patents, and permissive legal systems could hamper incentive to innovation activity, there by reducing investment and innovation, and thus economic growth. Details of this argument are provided by Murphy et al.⁽¹⁹⁹³⁾

(5) For the endogenous innovation model, foreign direct investment and multinational corporations (MNCs) seem to play an important role in technology transfer and thus growth for most developing countries. The spillover effect is likely to exist, but it is still not clear how it might occur.

(6) The adoption of new technology is often dependent upon the availability of complementary inputs and supporting infrastructure. In agriculture, a necessary marketing infrastructure and available inputs affect farmers' decision to adoption new technology, such as new crop.

(7) It has been well known for rural sociologist that farmers in developing countries are risk averse, particularly small farmers. Adoption of technology is not instantaneous after innovation is made.

Concluding Remarks

The advances in new growth theory, reviewed in this section, help us explain why

some countries grow faster than others. In addition, the new growth theories provide us theoretical grounds for policy to affect a country's growth performance. The human capital accumulation models, developed by Lucas and Romer and endogenous innovation models, proposed by Grossman and Helpman, provide means for improving our understanding of the possible connection between the trade policy regime including global environment and long-run growth. Even though the developing countries potentially stand the most to gain from their international relationship in the light of these new theories, some observations have been made against their implications.

3. Human Capital and Theory of Economic Growth

Human capital takes a central role in many theories of economic growth. There are two broad approaches hypothesizing the channels through which human capital can affect output growth. The first approach, initiated by Lucas (1998) and inspired by Becker's (1964) theory of human capital, is the neoclassical framework. This framework is based on the idea that human capital is a factor of production. Growth is driven by the accumulation of human capital. Differences in growth rates across countries are explained by differences in the rate of human capital accumulation. The second framework is the Nelson-Phelps approach. According to Nelson and Phelps (1966), human capital stock drives growth by affecting a country's ability to innovate or catch up with more advanced countries. Differences in growth rates across countries are then primarily due to differences in stock of human capital and thereby in countries' abilities to create technological progress. The main difference between these two approaches is their emphasis on the rate and the level of human capital.

3.1 The Neoclassical Framework

In the neoclassical growth model, Solow (1956) uses a macroeconomic Cobb-Douglas production function with homogenous labor and physical capital, which can be accumulated. Lucas (1988) formalized the Solow's model by including human capital as an additional factor that can be accumulated as well. Lucas considers an economy populated by infinitely

lived individuals who choose at each date how to allocate their time between current production and skill acquisition. This skill acquisition or accumulation of human capital increases productivity in future periods.

The production function is specified as follows

$$Y = K^{\alpha} (uH)^{1-\alpha} \quad (1)$$

where Y denotes the output, K the physical capital stocks, H the current human capital stock of the representative agent, and u the fraction of her time currently allocated to production. The specification in production function assumes the constant returns to the accumulation of physical capital and human capital.

The accumulation of physical capital is similar to the Solow or Ramsey models, namely

$$\dot{K} = Y - C \quad (2)$$

where C denotes the aggregate consumption. The black dot denotes time derivatives.

The basic human capital accumulation is as

$$\dot{H} = B (1 - u) H \quad (3)$$

where $B > 0$, and $(1-u)$ is the portion of time devoted to accumulate more human capital.

A positive growth rate in steady state is equal to

$$g = B(1 - u^*) \quad (4)$$

where u^* is the optimal allocation between production and education.

Lucas generalizes the production in (1) by allowing for spillovers from human capital acquisition of the form

$$Y = K^{\alpha} (uH)^{1-\alpha} (H_a)^{\gamma}, \text{ where } H_a = \frac{1}{n} \sum_{i=1}^n H_i$$

where H_a denotes the average human capital stock across individuals. The last term captures externalities stemming from the average stock of human capital (where each agent takes as given). With this generalization, a sustained growth rate of output is easily achieved.

Although the Lucas model is elegant and simple, it has been criticized for unrealistic assumption on the role of education. In (3) an individual's returns to education remains constant over time. This assumption is at odds both with the empirical evidence and with

Becker's theory of human capital. Becker (1964) suggests that returns to education tend to decrease over the lifetime of an individual. One easy way to deal with this criticism is to reformulate in the context of an overlapping generation framework.

Second generation model have enriched the basic approach, adding refinement such as finite individual horizons, overlapping generation, transference of human capital across generation. Azariadis and Drazen (1990) extends Lucas (1988)'s model to show the existence of low-development traps in the context of the OLG model with human capital accumulation. This model argues that human capital begets the production of more human capital: education and other sectors that produce human capital are intensive users of skilled labor. This means that rates of return in investment in human capital may initially rise instead of fall as the stock of human capital increases, because the large stock makes it cheaper to produce more. This means that difference in initial condition can lead to different long run growth path. The result is multiple steady state, one with low output, little human capital investment and high fertility³; the other with high returns, greater investment, a skills, and growth and lower fertility rate.

Glomm and Ravikumar (1992) emphasized on the role of human capital and inequality. They analyzed how the heterogeneous access to human capital across individuals of a same generation can affect the dynamics of inequality and growth. The main distinguishing features of their model are twofold. First, human capital endowments are unevenly distributed across individuals born at a same date. Second, the externality depends on the way education is being financed.

3.2 The Nelson-Phelps Approach

This framework views human capital as the source of technology progress. The idea was first proposed by Roger (1962). Roger found that the farmer with a relatively high level of education has tended to adopt productive innovation earlier than the farmer with relatively

³ Becker, Murphy, and Tamura (1990) emphasized on the fertility rate that the low development traps would generate more population (high fertility rate) and vice versa.

little education. Rogers argued that the greater education of the more educated farmer has increased his ability to understand and evaluate the information and infrastructure.

Based on the idea of Roger (1962), Nelson and Phelps (1966) developed the model in which the growth rate of total factor productivity depends on the stock of human capital. Human capital stock can affect technology progress by two channels: technology innovation and technology adoption. In either case, the growth of total factor productivity (A) is positively correlated with the level of human capital stock. This relationship implies that the growth rate of output depends on the growth rate of total factor productivity and the growth rate of total productivity depends on the level of human capital.

The Nelson and Phelps' idea was formalized by Benhabib and Spiegel (1994). We explore the model below.

Assume the economy has the Cobb-Douglas production function as

$$Y_t = A_t K_t^\alpha L_t^\beta \quad (5)$$

where Y_t is output, K_t is physical capital and L_t is labor. The parameters α and β represent the factor shares of each factor, subscript t represents time. The term A is generalized as the Solow residual term. It represents partially the level of technology and we use the residual as a proxy of technology. Also assume that the economy has the constant returns to scale ($\alpha + \beta = 1$).

Taking log difference, we obtain

$$\begin{aligned} \log Y_t - \log Y_{t-1} = & \log A_t - \log A_{t-1} + \alpha (\log K_t - \log K_{t-1}) \\ & + \beta (\log L_t - \log L_{t-1}) \end{aligned} \quad (6)$$

where $\log Y_t - \log Y_{t-1}$ is the growth rate of output, $\log K_t - \log K_{t-1}$ is the growth rate of capital, $\log L_t - \log L_{t-1}$ is the growth rate of labor and $\log A_t - \log A_{t-1}$ is the growth rate of technology.

Assume that the growth rate of technology depends on two sources. The first source is domestic innovation. The rate of domestic innovation is assumed to depend on the level of human capital, as in Romer (1990) and Jones (1995). Applying this idea, we can express the accumulation of technology as

$$\log A_t - \log A_{t-1} = g(H_t) \quad (7)$$

where $g(H_t)$ represents the innovation as a function of the level of human capital at time t . Assume that the innovation is positively correlated with human capital, so the first derivative with respect to human capital is greater than zero.

Another source of technology progress is the ability to absorb technology from abroad. Based on Welch (1966), Nelson and Phelps hypothesize that educated workers have more ability to absorb technology because they have more ability to learn. The more workers are educated, the more ability to learn and to use the new technology.

In particular, they suggested that the growth rate of technology depend on the gap between its level and the level of technology knowledge. Thus, the technology progress can be stated, from this source, as

$$\log A_t - \log A_{t-1} = c(H_t) \left[\frac{A_{m,t} - A_t}{A_t} \right] \quad (8)$$

where $A_{m,t}$ is the technology frontier at time t , A_t is the level of knowledge of country studied. The term $c(H_t)$ represents the speed of country to close the knowledge gap at time t , and assume that the speed of adoption depends on the level of human capital. Assume that the innovation is positively correlated with human capital, so the first derivative with respect to human capital is greater than zero.

Combining on both ideas, the growth rate of technology is

$$\log A_t - \log A_{t-1} = g(H_t) + c(H_t) \left[\frac{A_{m,t} - A_t}{A_t} \right]. \quad (9)$$

In (9) technology progress depends not only on the level of human capital but also the gap of technology. To estimate the effect of human capital directly, we can write equation (9) as

$$\log A_t - \log A_{t-1} = [g(H_t) - c(H_t)] + c(H_t) \left[\frac{A_{m,t}}{A_t} \right]. \quad (10)$$

The last term on the right hand side is the catch-up term. It represents the effect of technology gap to technology progress. And the variables in the first blanket on the right hand side represent the effect of human capital.

For simplicity, assume $g(H_t)$ and $c(H_t)$ have the simple linear relationship to human capital. Assume that the innovation and catch-up can be expressed as

$$g(H_t) = gH_t, \quad (11)$$

$$c(H_t) = mH_t \quad (12)$$

where g and m are the parameters that represent the speed of innovation and the speed of technology adoption, respectively.

Substituting equation (11), (12) into (10) and substituting (10) into (6) yields

$$\begin{aligned} \log Y_t - \log Y_{t-1} = & \\ & (g - m)H_t + mH_t \left[\frac{A_{m,t}}{A_t} \right] + \alpha (\log K_t - \log K_{t-1}) \\ & + \beta (\log L_t - \log L_{t-1}) \end{aligned} \quad (13)$$

In (13), the growth rate of output depends on the level of human capital, technology adoption, growth of capital, and the growth rate of labor.

Equation (13) can be shown in the per-worker form as

$$\begin{aligned} \log Y_t - \log Y_{t-1} & \\ = (g - m)H_t + mH_t \left[\frac{A_{m,t}}{A_t} \right] + \alpha (\log k_t - \log k_{t-1}) & \end{aligned} \quad (14)$$

The lower-case letter denotes the per-worker term. The last equation provides a structural relationship between output growth and its determinants.

3.3 The Hybrid Model: Complementarity between Human capital and R&D

Previous models emphasize the relative importance of human capital formation in driving sustained productivity growth. Recent literature has focused on the complementarity between human capital and new technology. Acemoglu (1997) and Redding (1996) have considered what happens when individuals can choose to make investments in education or training, while firms make investments in R&D. For some parameter values, multiple equilibria are possible, since the incentives of workers to invest in human capital, and those of firms to invest in R&D, are interdependent. Ellis and Roberts (2000) develop an

endogenous growth model in which new technology and new skills are bounded complements. Both technological progress and human capital accumulation are necessary for growth, but neither alone is sufficient. Moreover, they are complements up to the point. The marginal productivity of each factor is constrained by the level of the other. There are growing evidence of strong complementarity between new technology and skill (Barter and Lichtenberg 1987; Goldin and Katz 1998).

That this complementarity is bounded implies that growth cannot proceed without technical progress and aggregate human capital accumulation. This provides a way of formalizing earlier ideas about the possible existence of a “low-skill, low-quality traps” in which low skills and slow rates of innovation reflect a coordination failure. This model suggests that, at the aggregate level, greater investments in education or training might raise expenditure on R&D, and vice versa.

4. Empirical Evidences

4.1 Evidences on the Neoclassical Framework

The Neoclassical framework views schooling as an investment in skills and hence a way of increasing worker productivity, thereby growth. This line of reasoning leads to growth accounting models in which output growth is derived from growths in factor inputs (physical capital, human capital and) and in technology. The early studies based on growth accounting method found substantial evidences of the effects of educational change on economic growth. For example, see Grilliches (1970), Dennison (1979), Maddison (1987), Jorgenson and Fraumeni (1993).

Another way of testing the Neoclassical framework is to estimate the relationship between the rate of change of human capital to output growth using cross-country regression. The influential paper on this analysis is Benhabib and Spiegel (1994). They found no statistically significant of the growth in mean yeas of schooling on the growth in GDP per capita among countries. Similarly, Pritchett (1996), regressing the rate of change of human capital to output growth, supported the Benhabib and Spiegel’ results.

Some explanations for this outcome are found in literature. Pritchett (1996) argued that measurement errors and poor proxy of human capital could lead to weak evidence of the role

of human capital growth to economic growth. Many studies employed enrollment rates in growth regressions has been criticized because they are not indices of the educational attainment of the current labor force but of the future labor force. Some study tried to avoid this problem by using the ratio of secondary school enrolment to the working-age population in their regression analysis, a variable that they interpret as a proxy for the human capital investment rate. Generally, measures of the direct attainment of the labor force (years of schooling) often produce weaker results than the use of enrollment rates because of lower variations in data. Moreover, there are difficulties in comparing educational measures across countries, particularly in regard to the quality of schooling. Besides the data measurement and quality issues, these growth regressions may face a specification problem in the equating relating education and other variables to output growth.

4.2 Evidences of the Nelson-Phelps Approach

The Nelson-Phelps approach implies the following testable hypotheses. First, productivity growth and the rate of innovations should increase with the level of education, especially the higher education reflecting the ability to absorb and develop technology. Romer (1989) found that the effect of human capital to output growth were significant by using the growth regression analysis. Barro and Sala-i-Martin (1994) and Benhabib and Spiegel (1994) showed the significance of the level of secondary and higher education attainment on the rate of productivity growth. Benhabib and Spiegel found that human capital is significant to explain as the source of innovation in the case of rich countries. The result showed the significant in the role of human capital as the source of technology adoption in the case of the poor countries. But the middle income countries were insignificant to explain on both innovation and adoption. Barro (1997, 1998) used the reduced form regression analysis on output growth. Average year of schooling from Barro and Lee (1993, 1996) was employed as the proxy of human capital. He found that human capital was significant to explain output growth.

A second testable hypothesis is that the marginal productivity of education is an increasing function of the rate of technological progress, reflecting the speed at which new

technologies are adapted and adopted. This second prediction of the Nelson-Phelps approach has also found empirical support by Benhabib and Spiegel (1994).

5. Concluding Remarks

In conclusion, it is still inclusive to specify the relationship between human capital and output growth as implied by the Neoclassical framework or the Nelson-Phelps approach. The Neoclassical Framework implies that current investment leads to a one-time surge in output as new human capital is applied in production. In contrast, the Nelson-Phelps framework implies that current investment, by raising the level of human capital, has a permanent effect on technical change and hence growth. It is interesting to explore further the model in which educational attainment and technology are complement. The model developed along this line is still in its infancy. Therefore, research along this line is promising.

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Measuring Human Capital in Thailand

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Abstract

This paper proposes new estimates for human capital stock in Thailand during 1985-2005. Avoiding of the popular methods such as enrolment ratio, average years of schooling, this paper offers a specification of human capital in money units as a function of the measured education. The Mincerian earning function is employed to estimate differences in worker productivity and in work experiences.

JEL Classification Codes: J24, J31, J82, I21

Keywords: Human capital, wage differentials, labor force, education

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1. Introduction

The emergence of the endogenous growth theory following Romer (1989) and Lucas (1988) has brought back the importance of human capital as a source of growth and technical progress. This vast literature hypothesizes many channels through which human capital can stimulate economic growth. As for a factor of economic growth, the accumulation of human capital may be of importance than the accumulation of physical capital (Barro 1998). In some literature, human capital is a stimulus to domestic activities, and facilitates the technology adoption and innovation (Nelson and Phelps 1966; Benhabib and Spiegel 1994)

Despite of the growing evidence of human capital as a source of growth in international context, no satisfactory measure of Thai human capital stock exists. Earlier studies of the human capital stock were misspecified by the simple use of the poor proxies such as average years of schooling of the working-age population, adult literacy rates, and school enrolment ratios. These proxies are based on an ad-hoc choice rather than by economic theory. Human capital theory offers a specification of the human capital in money units as a function of the measured education. The incorrect misspecification of the education-human capital relationship is probably the cause of poor identification of the role of human capital stock and economic growth in previous studies.

The objective of this paper is to estimate Thailand's human capital stock from 1985 to 2005 based on the human capital theory. We follow two recent extensions of the specification of human capital appeared in literature. *First*, we allow for decreasing returns to investment in education by combining years of education with rates of return to education, as proposed by Bils and Klenow (2000). A Mincerian equation is specified to relate education and human capital. *Second*, we try to account for differences in the quality of education, especially though the inclusion of a cognitive skill index into the human capital function, as suggested by Gundlach et al (1998) and Heckman (1999). Thus, measuring the human capital embodied in the labor force is to specify the correct form of the relationship between education and human capital, allowing for decreasing returns to education and differences in the quality of a year of education.

Our constructed index of aggregate human capital indicates that this index grows on average 4.78 percent per annum and shows more fluctuation than the labor force. Over the periods 1985-2005, this index shows upward trends with some faster rate of increase since 2000 after the enactment of the 1999 National Education Act. The estimation approach adopted here is similar to Laroche and Merette (2000) and Wangudom (2001). Laroche and Merette estimated Canada's human capital stock while Wangudom estimated human capital stock for Thailand. Although allowing for productivity difference among labor force, both studies assumed no changes in these productivity differences. Using his estimates, Wangudom found no relationship between economic growth and level of human capital stock.

The improved measure of aggregate human capital has many potential uses. First, the better estimates of human capital may have an important caveat for economic analysis of its role to economic performance. The obvious example is its use in growth accounting, a method to assess the role of capital accumulation and technological changes (Solow residuals). Moreover, it allows policy makers to more fully understand the role of human capital to economic development.

Second, rapid changes in demographic factor could affect the quality of its labour force. With a suitable measure of human capital per worker, we can estimate more accurately the changing pattern of the effective labour force.

Third, a proper measure of human capital will be useful in testing the competing models. A better and more precise estimate of human capital will yield different parameters in economic models, possibly implying different policy implications.

This paper is organized as follows. Section 2 reviews the measures of human capital used in the growth regression literature. Section 3 describes the methodology and the data used to measure Thailand's human capital stock. Section 4 presents the results; and Section 5 concludes our study.

2. Literature Review

This section briefly reviews measures of the stock of human capital in the literature. The early contributions to the literature specified the stock of human capital in the labor force by using proxies. These proxies include education-augmented labor input, adult literacy rates, school enrolment ratios, and average years of schooling of the working-age population. Choices of specification partly reflect data availability. These proxies, however, did not give satisfactory measures of the human capital stock. We briefly discuss these concepts below.

2.1 Adult Literacy Rates

Literacy can be defined as the people ability to read and write a simple sentence with understanding. Adult literacy rate measures the proportion of adult who are literate of to total population.

$$l = Lr / PA$$

where l is the adult literacy rate, Lr is the number of literates in the adult population, and PA is the total adult population.

This proxy obviously reflects a component of the relevant stock of human capital. Adult literacy only grasps the first stage of human capital accumulation (writing, reading, and arithmetic). However, it ignores most of the investments made in human capital over lifetime. Any investment beyond the acquisition of basic literacy is neglected in this measure. Using such a measure assuming that knowledge and skills acquired beyond basic levels do not contribute significance to productivity. Hence, adult literacy rates underestimate the total stock of human capital.

Although many drawbacks, this proxy was used in many studies of cross-country growth regressions (Romer1990, Azariadis and Drazen 1990). Since the data set of adult literacy published by UNESCO and the World Bank, and the data for a large number of countries compiled by Summers and Heston (1988, 1991) are available, it was used as a proxy for human capital in many cross-countries analyses.

2.2 School enrolment ratios

School enrolment ratios is normally defined as the number of students enrolled at a grade level relative the corresponding school-age group. These enrollment ratio have been used to proxy for human capital in many studies (Barro 1991; Mankiw et al 1992; Levine and Renelt 1992). But as pointed out by Gemmell (1996), the enrollment rate is not suitable for the proxy of human capital because it cannot distinguish between stock and flow.

2.3 Average Years of Schooling

The average years of schooling is another popular method for measuring human capital. This method implicitly assumes that productivity is linearly related to numbers of schooling years. Workers with higher years in schools are more productive and able to learn from work experience. Thus, human capital can be measured as

$$H = \sum_s \phi_s \rho_s L \quad (1)$$

where subscript s represent the level of schooling; ρ_s is the share of worker with s year of schooling [$\rho_s = L_s / L$]; and ϕ_s is the weighted parameter for s level of schooling. In (1), each type of worker contributes to human capital according to his productivity (ϕ). Under this approach, the weighting parameter is the year of schooling at each level of schooling.

This method is popular for its ease in calculation. However, some drawbacks are noted. Importantly, this method assumes that differences in worker productivity is proportional to differences in numbers of schooling. In other words, one extra year in school is assumed to increase worker productivity at the constant rate. Thus, this cannot take into account changes in school quality over times.

(2.4) Income-based approach

To correct the drawbacks discussed above, the income-based approach uses the remuneration of the worker in the labor market rather than the years of education as weighing terms in (1). Human capital can be measured by

$$H = \sum_s \psi_s \rho_s L \quad (2)$$

where ψ_s is the earning from the worker with s year of schooling. The weighting parameters for each level of education are thus the efficiency parameters for each educational level, and needs to be estimated.

This approach assumes that productivity increases non-proportionately with years of education. Workers with different educational levels are not assumed to be perfectly substitutes. For reviews of this approach, see Le and others (2004).

Next section discusses how we employ this income-based approach to measure the aggregate human capital, and how we estimate these efficiency-weighting terms- using the human capital theory to determine the structural relationship between earnings and education.

3. Methodology

As discussed earlier, the more appropriate way is to allow for the fact that workers with different productivity receive different earning. Thus, the weighting parameter to aggregate the human capital from different levels of educational attainment should reflect differences in productivity. It is well known in labor economics that wages or productivity depends on both years of educational attainment and experiences. Thus, we can measure human capital by

$$H = \sum_s \sum_x \psi_{s,x} \rho_{s,x} L. \quad (3)$$

The weighting parameter can be defined as

$$\psi_{s,x} = e^{(\gamma s + \eta x + \mu x^2)} \quad (4)$$

where s is year of schooling, x is years of experiences, and η , μ , γ are parameters to be estimated. To estimates these parameters, we employ the popular Mincerian earning equation.

Mincer (1974) showed that if the only cost of attending school and additional year is the opportunity cost of student's time, and if the proportional increase in earning caused by

the additional schooling is constant over the lifetime. Thus, the log of earning would be linearly related to individual's year of schooling. Moreover, he included working experiences in quadratic form to capture for returns on the-job-training. The popular Mincerian earning function is as:

$$\ln w = \gamma s + \eta x + \mu x^2 \quad (5)$$

where the parameter γ measures how wages rise with the year of schooling. The parameter η and μ measure how wages change with working experience. Variables s and x represent the level of schooling and age of experience respectively. The popularity of this specification is the benefits of deriving rate of returns to education as coefficients of education variables, γ .

This equation implies that a percentage increase in earnings is strictly proportional to years in schools. The response of changes in earnings to changes in years of schooling is equal to the rate of return to education. That is, the natural logarithm of earnings is linearly related to amounts of time spent in school. This implies that earnings of the workers is increasing with the lengths of education year. The square term of experience variable is added to capture the nonlinear effects of experiences on earning.

The method applied here is similar to Koman and Marin (1997), Laroche and Merette (2000). The difference is that we adopt simple way to aggregate human capital using equation (3) and (4) above. Koman and Marin (1997) assumes a Cobb-Douglas aggregator to relate workers with different education levels to human capital as follows:

$$\ln\left(\frac{H}{L}\right) = \sum_s \omega_s \ln(\rho(s)),$$

where

$$\omega_s = \frac{e^{\gamma s + \eta x + \mu x^2} L(s)}{\sum_s e^{\gamma s + \eta x + \mu x^2} L(s)}.$$

$\rho(s) = L(s) / L$ or the proportion of working age individuals with s years of education. Similarly to our method, ω_s is the efficiency parameter of a worker with s years of education.

Wangudom (2001) used the same technique to estimate the aggregate human capital in Thailand during 1977-1999. In his study, he assumed that one year of schooling generates the same amount of skills over time by using a fixed-weighted measure using the Labor Force Statistics in 1996. In this study, we will allow these weighted measure to evolve over time. The changing value of the efficiency parameter of a worker with s years of education will reflect labor market conditions for various types of education. More importantly, this will also take into account changes in quality of education over time.

One possible problem with the estimated human capital using one fixed-weighted measure of efficiency could be serious if educational quality differs over time. Educational quality or accumulated cognitive skills are very difficult to measure. As in many other studies, Barro and Lee (1996) used educational expenditure per student, student-teacher ratios, teacher salaries to proxy for the quality of inputs. As argued by Hanushek (1996), previous studies in many countries found that educational inputs or resources used cannot enough explain educational outputs. In aggregate level, quality of educational output will depend on the effectiveness of input uses and its allocation. Hanushek and Kimko (2000) used the composite index of test scores to proxy for educational quality. Punyasavatsut and others (2005) used the National test score to measure educational quality in Thailand. Although using test scores for reflecting educational quality seems to be appropriate, this method is not possible due to limited data. To solve this problem, our method will allow for changing parameters of efficiency of each education level by employing various years of labor force statistics. The quality dimension should then be incorporated and valued by the labor market.

Data Specification

This study employs the Labor Force Survey (LFS) data from the National Statistics Office during 1985-2005. The LFS data provides earnings by educational levels of Thai workforces. The experience variable, followed Mincer (1974), is the current ages minus year of schooling and minus six.

4. Results

Table 1 and 2 shows structure of Thai labor force during the periods of study. Respondents are classified by their educational levels. Noting that education classification is not standard throughout periods of study. Mean of earnings of respondents classified by educations are reported in Table 2. We normalized them by using the mean of earnings of respondents who have received no education. It thus shows annual earnings of different categories as the multiple of those of worker class who have received no education. Table 4 shows predicted annual earnings by educational levels. Those who receive no education and experiences will get the base weight amounted 1. Similarly, figures in Table 4 thus present the relative earning or efficiency parameter as required in Equation (4). Predicted earnings were calculated using the estimated parameters from the Mincerian regression.

Table 4 presents estimation results from the Mincerian equation as specified in (5). The second column can be interpreted as returns to education. Rates of returns to education was around 10-12 % per annum. Using the results from Table 3, we can calculate the aggregate human capital value and index for Thailand. Before constructing the human capital, aggregate numbers of labor force are ensured to yield the consistent numbers over times. Figure 1 shows labor force in Thailand. Over the periods of 1985-2005, labor force grew at the rate of 1.5 % per annum on average. Figures 2 and 3 show the constructed human capital index based on relative earning and predicted earnings, respectively. As for the human capital index, we normalized the value of human capital in our beginning period of estimation to be one in both calculations.

Both constructed aggregate human capital show upward trend since 1985. The first human capital index grows on average 2.47 % per annum and is somewhat fluctuated. The second aggregate human capital index grows on average 4.78 % per annum and shows less fluctuations than the first one. Both indexes show more fluctuation over time than the labor force. The results show that Thailand's aggregate human capital index grew faster since 2000 after the enactment of the 1999 National Education Act.

5. Concluding Remarks

This paper shows estimates of aggregate human capital stock for Thailand during 1985-2005. The estimation is based on the income-based approach. With this approach, a

worker's productivity is measured by his or her earnings in the labor market. In contrast to average years of schooling approach, this method allows for nonlinearity between years of education and labor productivity. This method uses information on completion of education levels and experiences of workforce to estimate workers' productivity and using them to construct the human capital value. A sensible measure of human capital will be useful in testing economic models and in deriving any structural parameters which are of policy interest. We present the applications of this useful results in the next chapter.

Table 1. Labor Force Survey By Educational Levels

Education Level	1985		1986		1987		1988		1989		1990	
Total	202,032	%	140,047	%	117,521	%	114,160	%	236,270	%	72,242	%
no education	16,739	8.3%	10,362	7.4%	9,217	7.8%	9,149	8.0%	17,400	7.4%	5,255	7.3%
below primary	34,355	17.0%	22,455	16.0%	17,648	15.0%	5,066	4.4%	10,077	4.3%	2,720	3.8%
lower primary	95,786	47.4%	64,344	45.9%	54,094	46.0%	56,679	49.6%	115,039	48.7%	33,837	46.8%
upper primary	29,726	14.7%	23,911	17.1%	20,203	17.2%	23,503	20.6%	54,487	23.1%	18,080	25.0%
Lower Secondary	10,972	5.4%	7,739	5.5%	6,550	5.6%	7,937	7.0%	16,128	6.8%	5,067	7.0%
Upper Secondary	3,076	1.5%	2,534	1.8%	2,180	1.9%	2,899	2.5%	6,218	2.6%	1,920	2.7%
Lower Vocational	17	0.0%	5	0.0%	4	0.0%	9	0.0%	14	0.0%	4	0.0%
Upper Vocational	4,861	2.4%	3,351	2.4%	3,045	2.6%	3,425	3.0%	6,677	2.8%	2,106	2.9%
University	1,759	0.9%	1,509	1.1%	1,267	1.1%	1,762	1.5%	3,658	1.5%	1,209	1.7%
University Professional	1,075	0.5%	1,073	0.8%	929	0.8%	1,306	1.1%	2,635	1.1%	879	1.2%
Teacher Trainings	2,805	1.4%	2,027	1.4%	1,823	1.6%	1,885	1.7%	3,496	1.5%	1,080	1.5%
Short-course training	51	0.0%	40	0.0%	57	0.0%	53	0.0%	81	0.0%	21	0.0%
misc	369	0.2%	204	0.1%	178	0.2%	180	0.2%	274	0.1%	52	0.1%
not reported	442	0.2%	494	0.4%	326	0.3%	308	0.3%	87	0.0%	14	0.0%

Table 1. Labor Force Survey By Educational Levels (continued)

Education Level	1991		1992		1993		1994		1995	
Total	229,888	%	227,338	%	70,750	%	361,958	%	273,787	%
no education	16,152	7.0%	15,139	6.7%	4,557	6.4%	21,721	6.0%	18,084	6.6%
below primary	8,151	3.5%	7,907	3.5%	2,488	3.5%	11,738	3.2%	7,925	2.9%
lower primary	109,044	47.4%	105,311	46.3%	31,984	45.2%	156,358	43.2%	116,204	42.4%
upper primary	55,430	24.1%	56,090	24.7%	18,148	25.7%	94,799	26.2%	66,864	24.4%
Lower Secondary	16,662	7.2%	17,524	7.7%	5,614	7.9%	33,809	9.3%	28,254	10.3%
Upper Secondary	6,332	2.8%	6,487	2.9%	2,060	2.9%	10,932	3.0%	10,325	3.8%
Lower Vocational	25	0.0%	8	0.0%	3	0.0%	9	0.0%	10	0.0%
Upper Vocational	7,115	3.1%	7,211	3.2%	2,244	3.2%	12,792	3.5%	10,274	3.8%
University	4,276	1.9%	4,328	1.9%	1,509	2.1%	8,171	2.3%	6,608	2.4%
University Professional	2,723	1.2%	3,007	1.3%	925	1.3%	5,361	1.5%	4,463	1.6%
Teacher Trainings	3,695	1.6%	3,954	1.7%	1,138	1.6%	5,757	1.6%	4,517	1.6%
Short-course training	60	0.0%	41	0.0%	20	0.0%	46	0.0%	32	0.0%
misc	171	0.1%	306	0.1%	45	0.1%	462	0.1%	226	0.1%
not reported	52	0.0%	24	0.0%	13	0.0%	4	0.0%	1	0.0%

Table 1. Labor Force Survey By Educational Levels (continued)

Education Level	1996		1997		1998		1999		2000	
Total	331,196	%	273,800	%	471,118	%	543,473	%	537,450	%
no education	22,397	6.8%	17,692	6.5%	27,058	5.7%	31,554	5.8%	28,448	5.3%
below primary	9,143	2.8%	7,767	2.8%	11,523	2.4%	13,357	2.5%	12,432	2.3%
lower primary	136,027	41.1%	110,116	40.2%	179,528	38.1%	201,954	37.2%	196,563	36.6%
upper primary	80,721	24.4%	66,552	24.3%	110,079	23.4%	125,931	23.2%	124,294	23.1%
Lower Secondary	37,871	11.4%	31,824	11.6%	62,834	13.3%	74,637	13.7%	76,583	14.2%
Upper Secondary	11,996	3.6%	10,755	3.9%	23,235	4.9%	28,878	5.3%	31,796	5.9%
Lower Vocational	10	0.0%	14	0.0%	13	0.0%	25	0.0%	22	0.0%
Upper Vocational	12,819	3.9%	11,366	4.2%	20,942	4.4%	23,645	4.4%	22,715	4.2%
University	9,497	2.9%	8,600	3.1%	17,471	3.7%	21,517	4.0%	23,227	4.3%
University Professional	5,518	1.7%	4,638	1.7%	10,093	2.1%	12,459	2.3%	12,681	2.4%
Teacher Trainings	4,944	1.5%	4,263	1.6%	7,985	1.7%	9,164	1.7%	8,445	1.6%
Short-course training	53	0.0%	31	0.0%	49	0.0%	59	0.0%	39	0.0%
misc	189	0.1%	177	0.1%	178	0.0%	157	0.0%	117	0.0%
not reported	11	0.0%	6	0.0%	131	0.0%	136	0.0%	89	0.0%

Table 1. Labor Force Survey By Educational Levels (continued)

ระดับการศึกษา	2001		2002		2003		2004		2005	
รวม	658,632	%	650,192	%	639,636	%	634,327	%	643,004	%
No education	35,233	5.3%	34,873	5.4%	33,523	5.2%	34,225	5.4%	33,966	5.3%
below primary	250,254	38.0%	241,503	37.1%	229,427	35.9%	217,460	34.3%	217,200	33.8%
Primary	135,042	20.5%	133,270	20.5%	128,762	20.1%	127,498	20.1%	128,035	19.9%
Lower Secondary	103,749	15.8%	104,731	16.1%	106,399	16.6%	107,308	16.9%	108,356	16.9%
Upper Secondary	48,021	7.3%	49,766	7.7%	53,073	8.3%	55,259	8.7%	57,606	9.0%
Lower Vocational	23,132	3.5%	21,970	3.4%	21,448	3.4%	21,856	3.4%	21,738	3.4%
Upper Secondary, general	466	0.1%	411	0.1%	382	0.1%	311	0.0%	376	0.1%
Diploma, general	822	0.1%	723	0.1%	747	0.1%	696	0.1%	887	0.1%
Diploma, vocational	17,401	2.6%	17,823	2.7%	18,802	2.9%	18,268	2.9%	19,292	3.0%
Diploma, teacher	1,469	0.2%	1,234	0.2%	1,159	0.2%	1,121	0.2%	1,118	0.2%
University	28,054	4.3%	29,221	4.5%	31,121	4.9%	33,954	5.4%	36,963	5.7%
University Professional	2,340	0.4%	2,188	0.3%	2,331	0.4%	2,714	0.4%	3,019	0.5%
Teacher Trainings	10,999	1.7%	10,523	1.6%	10,579	1.7%	11,171	1.8%	11,442	1.8%
misc	251	0.0%	268	0.0%	322	0.1%	415	0.1%	372	0.1%
not reported	1,399	0.2%	1,688	0.3%	1,561	0.2%	2,073	0.3%	2,633	0.4%

Source: Author's calculation from Labor Force Survey, National Statistics Office, various years.

Table 2. Relative Earnings by Educational Levels, 1985-2005

weighting \ year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
no education	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
below primary	1.40	1.09	1.21	1.14	1.02	1.24	1.16	1.45	1.36	1.44	1.61	1.46	1.50	1.45	1.48	1.22
lower primary	1.50	1.46	1.40	1.29	1.45	1.57	1.59	1.81	1.90	1.80	1.87	1.87	1.94	1.92	1.92	1.78
upper primary	1.20	1.05	1.15	0.88	1.02	1.23	1.16	1.32	1.35	1.35	1.43	1.54	1.57	1.67	1.60	1.55
Lower Secondary	2.15	2.20	1.98	1.73	2.06	2.27	2.15	2.55	2.54	2.40	2.54	2.42	2.34	2.34	2.25	2.15
Upper Secondary	2.17	2.06	2.06	1.68	1.91	2.06	2.07	2.60	2.59	2.46	2.58	2.31	2.51	2.30	2.26	2.04
Lower Vocational	2.45	2.25	2.29	2.03	2.06	2.53	4.98	6.23	3.21	2.27	4.09	1.77	5.24	2.07	2.04	2.66
Upper Vocational	2.69	2.45	2.42	2.19	2.45	2.60	2.75	3.25	3.24	3.18	3.29	3.06	3.12	3.08	3.08	3.04
University	4.46	3.97	4.21	3.80	4.19	4.67	4.99	5.84	6.40	5.73	5.67	5.86	5.87	5.46	5.26	4.84
University Professional	3.07	2.60	2.49	2.14	2.51	2.81	2.94	3.63	3.69	3.44	3.56	3.46	3.59	3.39	3.20	3.00
Teacher Trainings	2.72	2.66	2.73	2.42	3.07	3.39	3.29	4.15	4.41	4.09	4.54	4.35	4.32	4.24	4.31	4.09
Short-course training	1.57	1.41	1.61	1.84	1.39	1.40	3.59	1.44	1.95	1.67	2.29	2.55	2.03	1.76	3.39	1.25
miscellaneous	2.84	2.00	3.10	1.88	7.20	1.19	4.86	9.02	5.66	4.77	4.17	0.37	3.51	1.41	3.47	1.10
not reported	2.80	2.49	2.12	2.18	2.17	0.91	2.13	2.56	3.92	4.83	5.00	6.40	6.25	6.08	1.96	7.92

Table 2. Relative Earnings by Educational Levels, 1985-2005 (continued)

Weight \ year	2001	2002	2003	2004	2005
no education	1	1	1	1	1
< primary	1.53	1.53	1.52	1.51	1.54
primary	1.33	1.35	1.35	1.33	1.39
Lower Secondary	1.80	1.74	1.68	1.69	1.74
Upper Secondary, general	1.80	1.73	1.71	1.72	1.78
Upper Secondary, vocational	2.65	2.45	2.48	2.40	2.53
Teacher Trainings	3.54	3.77	3.90	4.37	4.77
Diploma, general	2.91	2.76	2.58	2.40	2.16
Diploma, vocational	2.61	2.40	2.42	2.45	2.51
Diploma, teacher	3.50	3.65	3.60	3.09	3.53
University, professional	4.72	4.49	4.50	4.52	4.52
University, vocational	3.57	3.49	3.50	3.48	3.75
University, teacher	3.79	3.70	3.85	3.95	4.28
miscellaneous	1.25	1.12	0.81	2.60	0.71
not reported	3.64	2.63	2.88	2.88	2.90

Source: Author's calculation.

Table 3. Predicted Relative Earnings By Educational Levels, 1981-2005

weighting \ year	year of schooling	1985-1994	1995-1997	1998-2000
no education	0	1.0000	1.0000	1.0000
below primary	2	1.2486	1.2288	1.2288
lower primary	4	1.5589	1.5098	1.5098
upper primary	6	1.9464	1.8552	1.8552
Lower Secondary	9	2.7156	2.5269	2.5269
Upper Secondary	12	3.7886	3.4418	3.4418
Lower Vocational	12	3.7886	3.4418	3.4418
Upper Vocational	14	4.7304	4.2291	4.2291
University	16	5.9062	5.1966	5.1966
University Professional	16	5.9062	5.1966	5.1966
Teacher Trainings	16	5.9062	5.1966	5.1966
Short-course tranining	14	4.7304	4.2291	4.2291
misc	14	4.7304	4.2291	4.2291
not reported	14	4.7304	4.2291	4.2291

Table 3. Predicted Relative Earning By Educational Levels, 1981-2005 (continued)

Weight \ year	year of schooling	2001-2004	2005
no education	0	1.0000	1.0000
< primary	2	1.2712	1.2687
primary	6	2.0544	2.0421
Lower Secondary	9	2.9447	2.9183
Upper Secondary, general	12	4.2207	4.1704
Upper Secondary, vocational	12	4.2207	4.1704
Teacher Trainings	12	4.2207	4.1704
Diploma, general	14	5.3656	5.2910
Diploma, vocational	14	5.3656	5.2910
Diploma, teacher	14	5.3656	5.2910
University, professional	16	6.8210	6.7127
University, vocational	16	6.8210	6.7127
University, teacher	16	6.8210	6.7127
miscellaneous	6	2.0544	2.0421
not reported	12	4.2207	4.1704

Source: Author's Calculation

Table 4. Estimation Results of the Mincerian Equation

Year	education	experience	experience squared	R-squared	No. of Obs.
1985	0.111 (0.005)	0.075 (0.010)	-0.001 (0.000)	0.42	2717
1995	0.103 (0.008)	0.017 (0.013)	-	0.45	7,655
1998	0.103 (0.004)	0.027 (0.007)	-	0.47	6493
2001	0.12 (0.0006)	0.05 (0.0009)	-0.0007 (0.00002)	0.44	45,873
2005	0.119 (0.0003)	0.055 (0.0004)	-0.0007 (0.000007)	0.5422	204,679

Source: Author's calculation from the Labor Force Survey data.

Note: - Dependent variable is log of annual earning.

- Estimates for 1985, 1995, and 1998 come from Hawley (2004) p. 279 for Thai men samples.

Table 5. Aggregate Human Capital Index for Thailand Using Relative Earning 1985-2005

year	Human capital Value	Index
1985	41,420,938	1.000
1986	39,697,137	0.958
1987	42,355,340	1.023
1988	40,157,700	0.970
1989	45,769,425	1.105
1990	51,314,798	1.239
1991	52,283,286	1.262
1992	62,445,016	1.508
1993	64,412,229	1.555
1994	61,887,698	1.494
1995	66,333,855	1.601
1996	66,146,893	1.597
1997	69,963,862	1.689
1998	70,951,738	1.713
1999	69,656,456	1.682
2000	67,690,708	1.634
2001	61,307,037	1.480
2002	61,359,238	1.481
2003	62,137,825	1.500
2004	64,438,037	1.556
2005	67,881,327	1.639

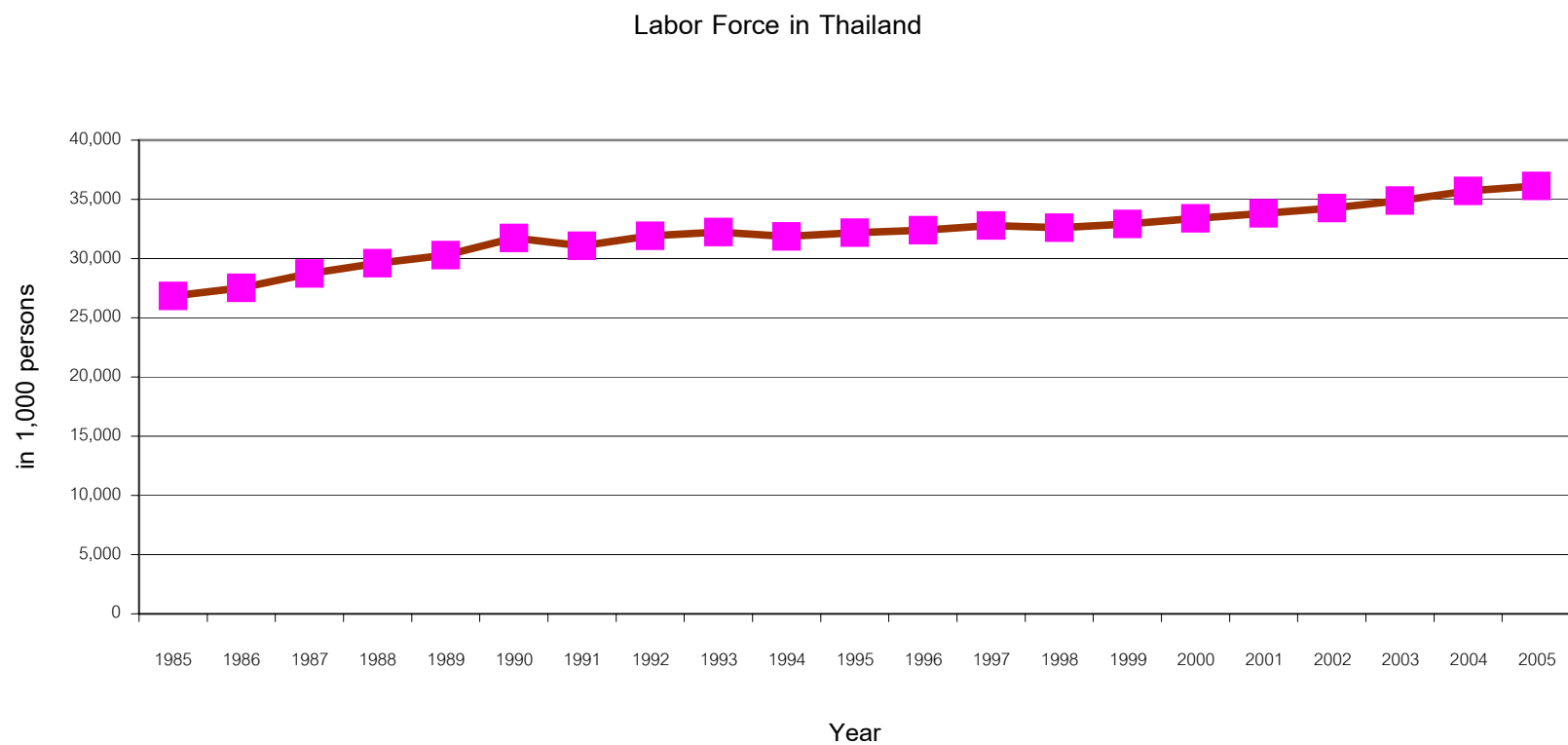
Source: Author's calculation.

Table 6. Aggregate Human Capital Index for Thailand Using Predicted Earnings Based on Mincerian Equation

year	Human capital Value	Index
1985	49,483,549	1.000
1986	52,163,193	1.054
1987	55,764,538	1.127
1988	61,516,490	1.243
1989	62,647,407	1.266
1990	64,480,652	1.303
1991	65,952,944	1.333
1992	68,479,326	1.384
1993	68,707,633	1.388
1994	69,741,676	1.409
1995	67,481,100	1.364
1996	67,714,662	1.368
1997	70,401,103	1.423
1998	72,925,557	1.474
1999	73,344,458	1.482
2000	75,961,540	1.535
2001	85,317,194	1.724
2002	87,581,375	1.770
2003	90,416,822	1.827
2004	94,918,108	1.918
2005	96,792,610	1.956

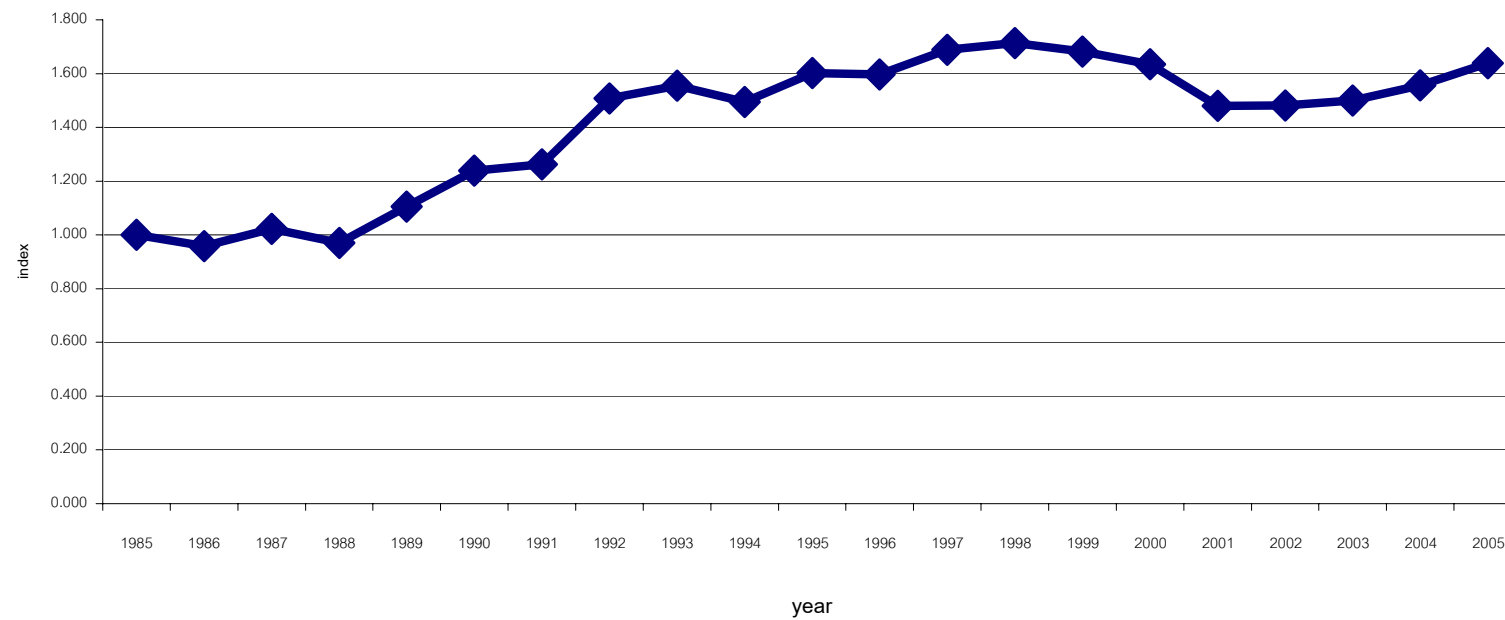
Source: Author's calculation.

Figure 1. Labor Force in Thailand 1985-2005



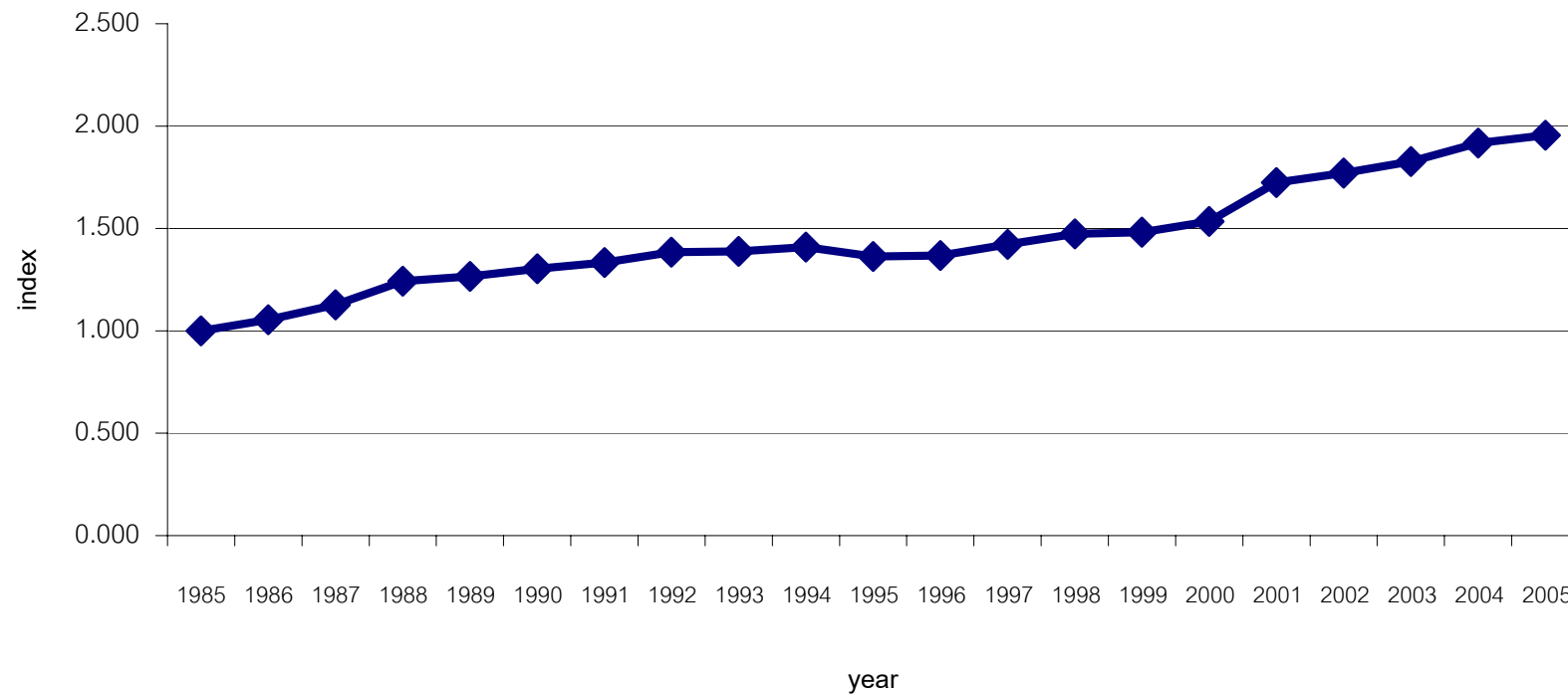
Source: Labor Force Survey, National Statistics Office, various years.

Figure 2. Thailand Human Capital Index 1985-2005 Using Relative Wage As Weighting Terms



Source: Author's calculation

Figure 3. Thailand Human Capital Index 1985-2005 Using Relative Earning from Mincerian Estimation As Weighting Terms



Source: Author's Calculation.

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Model of Growth with Externality for Thailand

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Abstract

This paper extends the model of growth with human capital externality proposed by Punyasavatsut and Coxhead (1999). The model shows that interactions between externalities that result from human capital accumulation and new technological opportunities embodied in imported intermediates create the possibility of "take-off", or sustained industrial growth. However, interdependence between the growth of technologically advanced domestic industries and the supply of human capital suggests a role for government in coordinating expectations between firms and institutions that supply higher education. Such coordination is a public good, and its provision should cause growth to accelerate. Policy to foster human capital accumulation is thus growth-enhancing. The paper also provides numerical simulation of the model using estimated parameters from Thai data. Numerical exercises are used to interpret aspects of the recent Thai growth and industrialization experience.

JEL Classification Code: H23, I28, J24, O14, O40

Keywords: Human Capital, Growth Theory, Externalities, Education, Industrialization

* I am indebted to Ian Coxhead for valuable suggestions. The usual disclaimer applies. E-mail address: chaoyuth@econ.tu.ac.th.

1. Introduction

In recent years, the notion of external economies, first introduced by Alfred Marshall (1920), has been widely used in many branches of economics. External economies can arise from knowledge accumulation (Romer 1986, 1990), human capital accumulation (Lucas 1988, 1993; Azariadis and Drazen 1990), and increases in aggregate demand through investment coordination (Murphy et al. 1989). Theoretically, only a single source of these externalities is sufficient to explain why some but not other countries can industrialize and become prosperous. Of these potential sources of externalities, it is possible that not only one but several may exist.

In the presence of external economies in production, many theoretical studies have shown that there may exist multiple equilibria in market economies. It will often happen that the greater the resources are committed to production with external economies, the higher is the return to those resources. Thus, committing resources toward this production may be desirable and may lead to a higher-income equilibrium. This idea has been widely applied to explain the industrialization process or a “takeoff” notion in recent literature, and also the successes of East Asian countries (Murphy et al 1989; Stokey 1991; Lucas 1988; Matsuyama 1991). Industrialization can be described as a process of shifting resources from agriculture (low-level or poverty trap) to manufacturing (high-level) ¹: a process associated with multiple equilibria of the economy. Punyasavatsut and Coxhead (1999) proposed a stylized model for Thailand in which human capital externality and imported intermediated goods play important roles for industrialization.

The goals of this paper are as follows: (a) To provide evidence of the existence of many kinds of Marshallian externalities associated with trade. We focus externalities in the Thai manufacturing group which is a base for industrialization; (b) we want to consider the broad applicability of the Punyasavatsut and Coxhead (1999) model. In particular, we will provide numerical calibrations using parameter estimates from this research.

Punyasavatsut and Coxhead (1999)’s model is based on three important

¹ The corollary view of this process is the declining share of agriculture in a country’s total income and labor forces.

characteristics from the industry level. *First*, domestic and foreign intermediate inputs are not perfect substitutes. New or more productive technologies may be embodied in machinery and equipment imported from abroad. To establish high-technology industries, a developing country needs to import these capital inputs. Casual observation from the Thai case suggests that through trade and capital liberalization, imported intermediate and capital goods have played significant roles in the beginning of the industrialization process.² Some empirical study showing a positive relationship between these imports and total factor productivity growth also support this observation (Punyasavatsut 1998). Empirical evidence from other countries also supports the idea that imported capital goods (machinery) contribute to growth (Temple and Voth 1998; Lee 1995; Jones 1994; De Long and Summers 1991; Findlay 1978). De Long and Summers claim that investment in equipment is exogenously determined by trade policies. Reducing tariff for imported equipment and machinery will raise growth and spur industrialization. Temple and Voth argue that there is a correlation between equipment investment and growth, and this correlation is strongest in a country on the brink of industrialization.

Second, human capital, or the educational attainment of the labor force, is an essential input in the production of high-end products (Schultz 1964; Nelson and Phelps 1966).³ With opening to trade, the successes of East Asian's industrialization have been attributed largely to a high level of education of their labor force (Pack 1992; Young 1995). Besides, there may be spillovers from human capital, either from its accumulation (Azariadis and Drazen 1990), or from learning by doing (Lucas 1988, 1993). In this paper, we focus on technological externalities from human capital accumulation. Using cross-country data,

² Thailand experienced strong growth, averaging almost 10 percent per year growth rates between 1987-1995.

³ In the literature, human capital can be treated as an ordinary input in the production function (for example, Mankiw, Romer, and Weil 1992), or as a factor stimulating and adopting new techniques (for example, Romer 1990). For the debate of whether the economy's growth depends upon the growth rate or the level of human capital, see for example Benhabib and Spiegel 1994. In this paper, we focus on the role of level of human capital in explaining industrialization.

Benhabib and Spiegel (1994) found that human capital stocks in levels determine the growth rate of total factor productivity.

Third, when industries are linked through backward (demand) and forward (cost) linkages, there are possible pecuniary externalities between industries. Demand linkages appear when an increase in the scale of operation of the downstream industry benefits upstream firms, and cost linkages when an expansion of the upstream industry leads to lower prices, giving benefits to the downstream industry. Due to such pecuniary externalities, simultaneous investment across industries, both upstream and downstream, can be profitable, and may be an essential step for takeoff. The idea that industrial linkages and varieties are conducive to industrialization and growth is argued by many scholars (Hirschman 1958; Rosenberg 1963; Jacobs 1969; Scherer 1982; Glaeser et al. 1992).

The basic idea is as follows. Consider an economy that consists of two sectors. The agricultural sector is perfectly competitive and employs only unskilled labor. The manufacturing sector contains upstream and downstream industries. We combine all industries into one aggregate industry, which implies that an industry produces intermediate goods and uses its outputs as inputs in its own production. In doing so, we can capture both demand and cost linkages between firms (industries) within the single aggregate industry. We assume that this industry is imperfectly competitive. The magnitude of this pecuniary externality depends on the strength of industrial linkages. The linkage parameter is assumed to be exogenous. Production of each domestic intermediate good requires skilled labor and the manufacturing composite, i.e. the composite goods between themselves and imported intermediates. Each intermediate good firm competes in monopolistic competition, pricing its product higher than the marginal cost of production. Free entry and exit guarantee zero profit, and the number of domestic intermediate firms is endogenously determined.

The logic behind the existence of multiple equilibria is based on two opposite forces: pecuniary externalities from industrial linkages and technological externalities from skilled labor employed in manufacturing. An increase in the availability of foreign intermediate goods reduces the cost of manufacturing production, thereby inducing new entrants. Competition in the product market forces firms to reduce their price to break-even point.

The magnitude of this cost-reducing effect depends on how strongly industries are linked. The stronger the linkage is, the more the cost is reduced. At the same time, an expansion of domestic intermediate firms increases the quantity of skilled labor, implying higher marginal productivity of labor as perceived by firms (as a result of technological externalities), and thus their wages. This effect increases the mark-up price. At the early stage of industrialization, the industrial linkage is likely weak. This implies a high share of skilled labor in total production cost. If the human capital externality is also strong, the price charged by domestic intermediate firms may be increasing as more firms enter. As a result, multiple equilibria arise due to the presence of both types of externality and an ensuing coordination failure.

The question of whether a country can escape from the low-income equilibrium (agriculture) and become industrialized by exploiting external economies is appealing for many developing countries. In the Thai case, there are two important reasons for this concern. The first arises in part from the sudden and very recent loss of comparative advantage in many labor-intensive industries to newcomers like China, Indonesia, and Vietnam. The second and more serious concern relates to the scarcity of human capital, domestic R&D, and infrastructure. These concerns raises the question of whether government should direct resources into manufacturing sector exhibiting externalities. Since external economies are external to firms, the market equilibrium is not Pareto optimal, thereby providing a basis for some government action.

Nonetheless, whether government should use industrial policy to guide and nurture industries exhibiting external economies is still a hotly debated question. Experience from the successes of East Asian economies suggest many variations in their policies, from Hong Kong's laissez-faire environment, to Singapore's forced domestic saving and encouragement of foreign investment, to South Korea's huge government-backed conglomerates, and Taiwan's investment subsidies (Young 1991; Wade 1990; Amsden 1989; Rodrik 1995). In the past decade, the Thai government policy on industrial development has been a mix of trade policy, particularly tariff policy, and investment incentives.⁴ Moreover, unlike Japan

⁴ Mingsarn (1992) argues that tariff policy has been Thailand's only industrial policy

and Korea, Thailand has played a limited role in “picking winners” and in coordinating investment.⁵ During 1987-1995, the “big-push” policy⁶ was not a serious concern, since the rate of investment in Thailand has been extraordinary high through foreign direct investment and foreign capital borrowing. Foreign direct investment from Japan, Taiwan and Hong Kong increased threefold during 1987-1990. Many heavy industries such as automobile, steel and petrochemicals have been initiated and expanded during this period. Their rapid expansion has been attributed to the liberalization of foreign trade policies during the late 1980s. Accompanying these huge inflows was a continuing tariff reduction on imported capital goods and intermediate goods in the early 1990s.

Based on our numerical exercise later in this paper, we will show that there is a possibility that a tariff reduction on imported intermediate goods might initiate the transition from a low-level to a high-level equilibrium, given that some assumptions made in the model are satisfied. This numerical exercise is intended to capture the major stylized facts of the Thai experience during the early of the 1990s.

The model to be developed below builds upon earlier models by Krugman and Venables (1995), and Venables (1996). We choose this starting point because these models highlight the role of industrial linkages in a simplified setting which is familiar in both the trade and economic geography literature. Extending Krugman and Venables (1995), Venables (1996) considers the effects of trade policy in triggering industrialization. Strong pecuniary externalities between firms generate multiple equilibria in his model. Since there

since 1960. Investment incentives provided by the Board of Investment (BOI) have been selective and thus more likely to create rent-seeking behavior.

⁵ Although the Thai government targeted some industries (food processing, textiles, electronics, petrochemicals, iron and steel) during the 7th national development plan (1992-96), there are no coordinating industrial policies initiated from government authority. Mingsarn (1992) provides a clear example of poor policy coordination in the automotive industry.

⁶ The “big push” idea goes back to Rosenstein-Rodan (1943); it states that a country can escape the underdevelopment trap and promote industrialization by coordinating investment across sectors.

is only one source of the externality, a country with weak industrial linkages cannot become industrialized when it liberalizes its foreign trade. This result can be considered as a shortcoming since a poor country mostly starts with industries that by their nature have weak linkages (e.g. food processing, and primary industries). Also there is no role for human capital, a necessary condition for industrialization, in his model.

Our model differs from the foregoing in that the supply of skilled labor is endogenized and there are technological externalities associated with its accumulation. The paper departs from the existing literature in demonstrating that the effectiveness of trade policy in picking the equilibrium outcome may depend on the fundamental structure of the economy, i.e. on the relative magnitudes of pecuniary and human capital externalities.

Many models that explaining industrialization have taken the supply of human capital as exogenous, however, we feel that this is not a satisfactory approach. This is because it is not always clear why a country starting with a low level of human capital makes education become attractive, as industrialization is taking place. Without protection of industry (through trade policies or investment subsidies), returns to education are lower when a labor-intensive country opens to trade, given that a country imports the human capital intensive product. This is known as a Stolper-Samuelson result. Since trade will emphasize the country's comparative advantage, there is less incentive to accumulate human capital. In the framework where human capital is exogenously determined, a country with a high initial stock of this factor will be fortunate enough to become industrialized if she choose to do so. In contrast, a poor country with initially low human capital endowment has no option (Rodrik 1996). Instead, this paper allows human capital to be endogenously determined. It also show that there is a link between human capital accumulation and the supply of foreign capital goods in the process of industrialization. Reducing the price for foreign capital goods will stimulate demand for skilled labor. At certain levels of human capital and the number of domestic high-tech firms, a country will be on the path to the higher-level equilibrium. Human capital increases along with the industrialization process. This idea can be considered as a hybrid of the two strands in the existing literature: one is to escape from the underdevelopment by increases in varieties of intermediate inputs (Rodriguez-Clare 1996;

Ciccone and Matsuyama 1996), and another is by accumulation of human capital, where spillovers occur when human capital reaches some critical mass (Azariadis and Drazen 1990).

The remainder of this paper is in five parts. Section 2 sets out the formal model. Section 3 describes instantaneous multiple equilibria, and shows how a change in trade policy helps trigger industrialization. Section 4 provide some evidence of existences of externalities in Thai manufacturing sector. Section 5 offers numerical examples of the effect of policy change on the equilibrium. The last section offers some concluding remarks and suggestions for future research.

2. A Basic Model

The model developed below builds upon the earlier model by Punyasavatsut and Coxhead (1999) which is an extension of Venables (1996). We consider an economy which contains two sectors, agriculture and manufacturing. The representative consumer receives only labor income, and has Cobb-Douglas preferences between agriculture and manufacturing. These preferences can be represented by an expenditure function

$$e = P_a^{1-\gamma} P_m^\gamma V \quad (1)$$

in which V is utility, P_a the price of agriculture, and P_m is the price index for manufactures, and γ is the share of manufactures in consumer expenditure.

Technology.

We assume that agriculture is perfectly competitive, and uses only unskilled labor with constant returns to scale. We assume that one unit of labor produces one unit of agricultural output. We assume the agricultural output price to be fixed at the border and, by choice of units, set $P_a = 1$. At equilibrium, if agricultural output is positive, the equilibrium wage of unskilled labor is also equal to 1.

Manufacturing contains downstream industries and upstream industries. Downstream industries are characterized by perfect competition, and upstream industries by monopolistic competition. Both upstream and downstream outputs are tradable, and subject to trade policy. Instead of working with distinct upstream and downstream industries, we borrow a

simplification developed by Krugman and Venables (1995). The trick is to combine activities into a single industry which produces both final and intermediate goods, and uses the intermediates as inputs in its own production. This aggregation combines the inter-industry linkages and transactions of the input-output table into one industry. We assume that the aggregate industry so created is imperfectly competitive. For simplicity, we employ the famous Dixit-Stiglitz (1977) method of modeling monopolistic competition, in which products are differentiated. This framework allows us to capture both demand (backward) and cost (forward) linkages between firms within a single industry. Industrial expansion increases demand for the output of firms in the industry since the new entrants demand intermediates from existing firms. As the new entrants provide new varieties of differentiated products, this will also reduce the costs of existing firms. Hereafter, we refer to both demand and cost linkages as “linkages”. To maintain our focus on a single economy, we assume that the output of the manufacturing sector is entirely consumed and not exported.

From consumer side, the differentiated products produced in the aggregate manufacturing can be aggregated by a CES sub-utility function into a composite good. The price index of this manufacturing composite is P_m , and takes the CES form

$$P_m = [n^d(p)^{(1-\sigma)} + n^f(p^f)^{(1-\sigma)}]^{\frac{1}{1-\sigma}}, \quad \sigma > 1, \quad (2)$$

where p is the price of domestically produced varieties, n^d is the number of domestic high-tech firms (=varieties), p^f the price of imported varieties, and σ is the price elasticity of demand between domestic and imported varieties. For $\sigma > 1$, this means no variety is essential. Without loss of generality, the number of foreign industries (=varieties) is set to be constant and equal to unity. The number of domestic industries is an endogenous variable to be determined by free entry and exit.

Firms in manufacturing use skilled labor and a composite manufacturing intermediate good to produce output. We make the major simplification that the composite intermediate good is the same as the composite consumption good. Thus the price index of intermediate goods is P_m as defined in (2) above. Labor and the intermediate are combined with a Cobb-Douglas technology with intermediate share μ . Each firm produces output x using α units of

the input as a fixed cost and β units per unit of output. In addition, there is an technological externality generated by human capital employed in this sector. We assume that the economies of scale associated with human capital are external to the firm but internal to the manufacturing sector. Both marginal cost and average cost are negatively related to the quantity of human capital employed in the sector. For simplicity, assume that the human capital externality can be represented by $A(H)=H^\lambda$. Then, the total cost of each firm is

$$C = [\alpha + \beta x] W_H^{1-\mu} P_m^\mu H^{-\lambda} \quad (3)$$

For $\mu > 0$, there are linkages. It is worth noting that there is also a cost reduction in making intermediate goods extensively used in the manufacturing sector. Therefore, production costs decline with n^d and with the accumulation of skilled labor in manufacturing at a given constant wage.

From (3), the corresponding technology of producing the domestic intermediate good can be recovered as

$$x = A(H)[H^{1-\mu} M^\mu] - \phi, \quad (4)$$

$$\text{where } \beta \equiv \left[\frac{1-\mu}{\mu} \right]^\mu + \left[\frac{1-\mu}{\mu} \right]^{\mu-1}, \quad \alpha \equiv \phi\beta.$$

The technology for producing the composite manufacturing good is

$$M = \left[\left(\int_0^{n^d} x(j)^\varepsilon dj \right) + \left(\int_0^{n^f} x^f(j)^\varepsilon dj \right) \right]^{1/\varepsilon}, \quad 0 < \varepsilon < 1, \quad (5)$$

$$\varepsilon = \frac{(\sigma-1)}{\sigma}, \quad \sigma > 1,$$

where $x^f(j)$ stands for the j -th foreign intermediate variety, and n^f for the number of foreign varieties.

Each firm maximizes operating profits, given by

$$\pi = p(x)x - C = p(x)x - [\alpha + \beta x] W_H^{1-\mu} P_M^\mu H^{-\lambda}. \quad (6)$$

Profit maximization implies that firms will use a mark-up pricing rule. Price exceeds marginal cost by a factor $1/\sigma$. For simplicity, we choose units of measurement such that $\beta = (\sigma-1)/\sigma$ and thus both terms are canceled out. Thus, the price of domestic intermediate goods is set as

$$p = W_H^{1-\mu} P_m^\mu H^{-\lambda} . \quad (7)$$

With free entry and exit of firms, industry equilibrium occurs when profits are zero. Since all the inputs are priced equally and enter symmetrically in the production function, all firms operate with the same scale. With price just covering average costs, i.e. $px = C$, a unique size of firm is:

$$\bar{x} = (\sigma - 1)\alpha/\beta = \alpha\sigma. \quad (8)$$

The equilibrium output level of each firm $\bar{x}$ is unique and determined by the demand elasticity between varieties and the relative magnitude of fixed cost to marginal costs. Hence, any change in the scale of the industries will have to come from a change in the number of firms.

Demand for each industry output (or variety), from both consumer demand and factor demand, is⁷

$$x = p^{-\sigma} P_m^{\sigma-1} E \quad (9)$$

where E is total expenditure on those industry output. At equilibrium, $x = \bar{x}$.

The total expenditure on manufacturing goods comes from two sources. First, there is consumers' expenditure on manufacturing product. With Cobb-Douglas preferences, a fraction γ of income is spent on the manufactured goods. Second there is expenditure generated from intermediate demand. With Cobb-Douglas technology, a proportion μ of costs is spent on intermediates. With the zero profit condition, revenue equals cost. Intermediate expenditure is thus equal to $\mu n^d p \bar{x}$. Then, we have total expenditure on industry output as

⁷ For proof, see Grossman and Helpman (1991, pp. 46-47).

$$E = \gamma(W_H H) + \mu p n^d \bar{x} \quad (10)$$

It remains to characterize the labor market. We derive inverse demand for skilled labor at the industry equilibrium from

$$\frac{W_H}{p} = (1 - \mu) H^{-\mu} M^{\mu}.$$

Thus, the skilled labor demand is given by

$$H = \left[\frac{(1 - \mu) M^{\mu} p}{W_H} \right]^{1/\mu}. \quad (11)$$

In deriving (11), we use the fact that the industrial productivity is increasing with the number of skilled labor employed. Since the economies of scale are external, firms will pay skilled labor the value of marginal product as perceived by them. The factor market equilibrium requires demand equal to supply for each type of labor. To close the model, it remains to characterize the market supply for skilled labor.

We make a simplified assumption that supply of skilled labor is adjusted in a costless and timeless manner. We postulate that human capital or skilled labor is endogenously determined by individual schooling decisions. Under this assumption, the equilibrium is instantaneous.

3. Instantaneous Multiple Equilibria

The supply of skilled labor or human capital is a result of individual schooling decisions. By "human capital" we mean a set of specialized skills that individuals can acquire by devoting time to education. The more time that he or she spends in school, the greater is the measure of human capital that he or she acquires. In this model, unskilled and skilled labor perform different tasks. Only skilled labor can be employed in the manufacturing sector. We thus treat these two types of labor as imperfectly substitutable inputs. In this model the quantity of skilled labor and its wage are both endogenized. Accumulated skilled labor directly affects the level of profits of intermediate firms, and thus

the number of firms.

We need to establish the decision problem facing each individual as regards the allocation of time. We borrow the basic framework suggested by Findlay and Kierzkowski (1983), which was later adapted by Grossman and Helpman (1991: 125-127). In this framework, there are four equilibrium conditions that relate the fraction of the population that chooses to acquire specialized skills, the level of educational attainment, supplies of unskilled and skilled labor, to the relative factor returns.

We assume now that the economy is populated with a continuum of agents. Each agent lives for a finite T period of time. The age distribution is uniform at any moment in time, with a density of N/T individuals of every age from 0 to T . The total population has a constant measure N for the number of newborns is equal to deaths. Let S be the number of years in school. We assume that an individual who spends S years in education receives the measure $h(S)$ of skill, where $h(\cdot)$ is an increasing and concave function and $h(0)=0$. Optimality conditions for educational investments are (1) Individuals are indifferent between acquiring skill and receiving no education at all,

$$\frac{W_H}{W_L} = \frac{1 - e^{-rT}}{(e^{-rS} - e^{-rT})h(S)}; \quad (12)$$

and (2) the marginal cost of spending S years in school is equal to its marginal benefit:

$$1 - e^{-r(T-S)} = \frac{rh(S)}{h'(S)}. \quad (13)$$

Let ω denote the fraction of the population that acquires skills. At any moment in time, a measure of $\omega SN/T$ attends school and is out of the labor force. Supply of unskilled labor will thus be

$$L_0 = (1 - \omega)N; \quad (14)$$

and of skilled labor with $h(S)$ will be

$$H = \frac{(T - S)}{T} \omega N h(S). \quad (15)$$

Equations (12)-(15) relate the fraction of the population that choose to acquire specialized skills, the level of educational attainment of the representative worker, and the

supplies of both inputs, to the relative factor rewards.

For an economy that is incompletely specialized in production, equations (2), (5), (8),(9), (10), (11) and (12) to (15) characterize an equilibrium, and can be used to find equilibrium values of the endogenous variables P_m , W_H , p , n^d , S , ω , L and H with exogenous parameters T , N and r .

The analytical solution is probably too complex. It is so because we need to solve the interdependence among the domestic intermediate goods price, wage differentials, and supplies and demands of skilled and unskilled labor simultaneously. For simplicity, we assume that at any moment in time, there is an equilibrium in the labor market. The equilibrium wage for skilled labor is increasing in the stock of human capital employed at the different points of equilibrium over time. By this simplification, our equilibrium is characterized by equations (2), (7), (9), (10) and (11) which can be used to find equilibrium values of variables P_m , W_H , p , n^d and E .

Before analyzing multiple equilibria, we describe basic mechanisms in the model. Increases in n^d , the number of intermediate input varieties, affect firms' profitability. There are three channels through which n^d shifts the demand curve of intermediate goods. *First*, an increase in n^d raises product market competition, reducing the price index, thus shifting the demand curve for the output of each firm down. The *second* and *third* channels operate when μ is positive, i.e. manufacturing uses manufactured goods as input. An increase in n^d creates extra expenditure on intermediate goods, raising E , and thus raising demand and profits of each firm. This is the demand, or backward linkage between firms. An increase in n^d also reduces the price index, thus lowering total cost and marginal costs, and thereby raising firms' profits. This is a cost, or forward linkage.

To analyze equilibria of the model, we can describe the model solution from equations (2), (7), (9), (10) and (11), and using equilibrium value of H in (11). As in Venables (1996), we construct two relationships between p and n^d . The first relation describes the profit maximizing price charged by each firm as a function of the number of domestic firms operating in the industry. We refer to this curve as CC. The CC schedule is derived by using (2) and (11) in (7).

$$(CC) \quad p = W_H^{1-\mu} \left[n^d p^{1-\sigma} + (p^f)^{1-\sigma} \right]^{\frac{\mu}{1-\sigma}}. \quad (16)$$

When there are linkages, i.e. when $\mu > 0$, then there is a cost linkage between firms in the industry. An increase in n^d raises the number of intermediate goods, reducing the price index, P_m . Firms receiving a cost reduction thus reduce the price they charge: this is the second bracketed term on R.H.S. of (16). However, an increase in n^d also raises the quantity of skilled labor employed in manufacturing. Since firms will pay more for labor of a higher productivity, so the price they charge will need to be raised: this is the first bracketed term on R.H.S. of (16). Given that μ is small, the latter force will dominate the former, implying an upward slope of the CC curve.

The second relation gives the price which firms charge other domestic firms (and also consumers) at the scale of operation required to break even or make zero profits. We refer to this line as BB. The BB line is obtained by using (2), (10) and (11) in (9) and the operating scale is at the industry equilibrium.

$$(BB) \quad \bar{x} = p^{-\sigma} \frac{\mu n^d p \bar{x} + \gamma p (1 - \mu) H^{1-\mu} M^\mu}{[n^d p^{1-\sigma} + (p^f)^{1-\sigma}]}. \quad (17)$$

When a new firm enters, the demand curve facing each firm will shift downward. A cut in demand causes firms further reduce their price in order to continue to sell at the break-even level: this is the denominator of (17). An increase in n^d also creates additional expenditures on intermediate goods, raising E . This effect depends on the degree of demand linkage in the input-output structure, and this is the first term in the numerator. Moreover, an increase in n^d induces a change in consumers' expenditure since the price index of the manufacturing goods is cheaper than before. The extent of this expenditure switching depends on the price elasticity of demand for aggregate manufacturing, γ : this is the second term in the numerator. The slope of the BB curve is ambiguous. However, if the first of these effects is not the most powerful, the BB curve will be upward sloping, reflecting the impact of the entry through the increase in wages in skilled labor market and thus the price.

The CC and BB curves are depicted in Figure 1. If there are positive linkages and strong externalities in factor market, the CC curve may be steeper than the BB curve at some

range as shown. For an initial level of $n^d > N_u$, profits are positive since the price charged (on CC) is less than the one required to break-even (on BB). At this level, demand is greater than that required to break-even. Positive profits induce entry of new firms. As more firms enter, a new equilibrium is reached at n_H where the profit is zero. At S_H , the equilibrium is stable, and could be called a high-tech equilibrium. For that level of N_u , the equilibrium is unstable. Similarly, if $n^d < N_u$ initially, the price is too high for firms to break even, thus all firms exit due to negative profits. At S_L , the equilibrium is stable, and could be called a low-tech equilibrium or a pre-industrialization state. Now, we explore the equilibria in which policies affecting human capital accumulation and its externalities could lead to a high-tech and stable equilibrium

Human Capital Policy

The result obtained in Figure 1 is the outcome of the presence of industrial linkages and an externality from human capital accumulation, given instantaneous adjustment in the labor market. The characteristics of the equilibrium solution vary with the strength of linkages, the magnitude of the human capital externality, and the price elasticity of demand for manufactured goods. Varying these parameter values could thus affect the curvatures of the CC and BB curves, yielding only one stable interior solution. This is a special case of interest for Thailand. Recent educational reform has led to fast increases in educational public expenditure policies. This leads to more accumulated human capital for the industrial sector. The effects of increases in average human capital or its externalities to productivity of the manufacturing sector could be also subject to the quality of education. We capture this efficiency parameter by the degree of human capital externality λ . When industrial linkage μ is low and the human capital externality λ is strong, the CC curve is steeper than the BB curve, yielding a stable interior equilibrium. The same type of desired equilibrium could be then possible when both types of externalities are strong and work in parallel. Next, we explore the questions of whether and how trade policy affect equilibrium outcomes.

Trade Policy

To analyze the effects of trade policy on development of industry, we consider changes in the price of imported intermediate goods, p^f . Consider, for example, a tariff reduction in imported specialized goods. For simplicity, we assume that there is no recycling of tariffs back into the economy, so that tariff revenue reduction has no distributive impact and thus does not affect the equilibrium. The decrease in p^f affects the domestic high-tech firms in two ways. *First*, a price reduction in imported intermediate varieties lowers the composite price index for manufacturing. This will shift the CC curve downward. *Second*, an increase in import competition switches expenditure to foreign firms, lowering the price that domestic firms charge in order to break even. This will shift the BB curve downward also. However, the curves need not be displaced by the same amount.

To see how tariff reduction can be effective in moving an economy from the low-level equilibrium to the high-level one, we first consider the case of a pre-industrialized economy, with $n^d = 0$. Setting $n^d = 0$ in the definitions of CC and BB gives

$$\begin{aligned} (CC) \quad p &= [W_H^{1-\mu}](p^f)^\mu, \\ (BB) \quad p &= \left[\frac{\gamma W_H H}{\bar{x}(p^f)^{1-\sigma}} \right]^{\frac{1}{\sigma}}. \end{aligned} \tag{18}$$

At $n^d = 0$, there will exist a p^{f*} such that the CC and BB schedules intersect. When p^{f*} is changed through trade policy, the relative magnitudes of the square bracketed term in (CC) and that in (BB) will determine whether the new CC curve lies above or below the new BB curve. From (18), it can be shown, however, that if the bracketed term in (CC) is greater than the bracketed term in (BB) and since σ is greater than 1 by assumption, the CC schedule will shift by more than the BB schedule. In this situation, industrial linkages are weak and the externality from human capital accumulation is strong.

Let us consider two cases. *First*, we consider the case when a tariff reduction will lead to the high-level equilibrium: a situation when industrial linkages are weak and the externality from human capital accumulation is strong. In Figure 2, the slope of the BB curve is flatter than that of the CC curve. At $n^d = 0$, the equilibrium is stable at S_L , the

situation before trade policy reform. Then, a reduction in the price of imported varieties will lead to an expansion of production, shifting the CC curve downward more than the BB curve. Both curves intersect once, at the point S_H with $n^d > 0$. At this level, the new high-level equilibrium is stable. Instead, if we increase the tariff, the CC curve will shift upward more than the BB curve. In this situation, the entire CC curve lies above the BB curve (not drawn). The new stable equilibrium is the one with the higher domestic price, but without changes in the number of domestic firms, i.e. $n^d = 0$. In this case, a tariff increase makes no further improvement in industrial development.

Second, we consider the situation when linkages are strong and the human capital externality is weak. If the human capital externality is sufficiently weak, the slope of the CC curve may be steeper than the BB curve (Figure 3). However, the CC curve will have a downward slope when the first [.] term in (16) is dominated by the second [.] term. A reduction in the price of imported intermediate goods will then shift the BB schedule down by less than the CC schedule.

In Figure 3, at $n^d = 0$, the initial equilibrium at U_L is unstable. A decrease in tariff on imported varieties causes production to expand, reaching a new stable equilibrium at S_H with a lower price charged for domestic industries. This case is similar to Venables (1996), where the linkage is strong.

In both cases we have considered, a reduced tariff for foreign intermediate goods is associated with an expansion of domestic intermediate firms. The resulting price for the domestic intermediate goods is, however, indeterminate, in the first case, and so is the price of the composite manufactured good.

In brief, the essential reason for multiple equilibria is the presence of two externalities: one is the pecuniary externality through industrial linkages between firms, and the other is a technological externality through human capital accumulation. In economies at early stages of industrialization, industrial linkages are weak. In the absence of vertical integration among upstream and downstream firms, a country can become industrialized by liberalizing its foreign trade in intermediate inputs. In our model, foreign intermediate inputs are essential for domestic manufacturing. Through weak industrial linkages but with strong

externality in human capital, an increase in these foreign intermediate inputs can stimulate demands for skilled labor and domestic varieties. This analysis shows that there is a possibility in which liberalized trade policy can trigger industrialization by moving resources into the manufacturing sector exhibiting external economies.

Several points should be noted. First, when there is no externality from human capital employed in manufacturing, the CC schedule (the markup pricing condition) will always slope downward, while the slope of the BB schedule (the break even condition) is ambiguous. As shown in Venables (1996), when there are weak industrial linkages, raising protection has a conventional effect: the reduction in competition with imported foreign goods allows domestic firms to reach the production scale needed to break even. This is the opposite policy implication from our conclusion: the difference rests crucially on our assumptions and parameter values. Second, when the inter-industry linkage is strong and there is weak externality from human capital, we derive the same conclusion as in Venables: reducing protection triggers domestic production or industrialization, a similar to the second case just described. Third, when both externalities are strong, many possible cases are possible. However, this likely yields an interior stable equilibrium.

4. Evidences of Externality

The model proposed in the previous sector emphasizes two important sources of externalities: human capital accumulation and imported intermediated goods. To identify them in the endogenous growth framework, we provide separated theories for each model below.

(a) Human Capital: We define the production function of the i -th industry as:

$$Y_{it} = \gamma_i (N_{1,it} h_{it})^{1-\alpha_i} K_{it}^{\alpha_i}$$

where Y_{it} is the value added of the i -th industry in period t , $N_{1,it}$ is the size of the labor force employed in that industry sector, and h_{it} is the average amount of human capital in period t available for industry i . So, $N_{1,it} \cdot h_{it}$ is effective labor units in industry i . Let us assume that

$$h_{it+1} = h_{it} e^{\beta_i n_{2t} + \delta_i \ln N_{2,it}}$$

where n_{2t} is the average fraction of time spent accumulating human capital and A_{it} measures the external effect of human capital accumulation. And let us assume that $A_{it} = N_{2,it}$, where $N_{2,it}$ is the total stock of human capital in industry i . Thus, the accumulating human capital has a positive external effect.

The growth rate of the i -th industry output is

$$\frac{Y_{it+1}}{Y_{it}} = [e^{\beta_i n_{2t} + \delta_i \ln N_{2,it}}]^{1-\alpha_i} \left(\frac{N_{1,it+1}}{N_{1,it}} \right)^{1-\alpha_i} \left(\frac{K_{it+1}}{K_{it}} \right)^{\alpha_i} \quad (19)$$

Equation (19) can be rewritten as

$$TFPG_{it} = (1 - \alpha_i)(\beta_i n_{2t} + \delta_i \ln N_{2,it}) = \beta_{0,i} + \rho_i \ln N_{2,it} \quad \text{where } i = 1, \dots, I \\ t = 1, \dots, T. \quad (20)$$

where $\beta_{0,i}$ denotes $(1 - \alpha_i)\beta_i n_{2t}$, and ρ_i denotes $(1 - \alpha_i)\delta_i$. Again, the industry with a larger scale of human capital employed ($N_{2,it}$) grows faster.

(b) Imported Intermediated inputs: The next model is a variant of Romer (1990).

Manufacturing growth arises from an increase in the number of available intermediate and capital goods in the sector. With trade, an industry can import intermediate and capital goods from abroad. Without trade, learning by doing can lead to the development of new and improved inputs to production. We first derive the model in which specialized inputs are domestically developed, and later extend it to include the effects of trade in these inputs.

In period t , only goods in the interval $[0, A_{it}]$ are available for the i -th industry. Production experience will expand the development of new specialized inputs as follows:

$$A_{it+1} = A_{it} e^{\beta_{0,i} + \rho_i \ln Y_{it}}$$

The production function for the manufacturing sector presents the idea that an increase in the variety of inputs leads to an increase in measured output (Ethier 1982).

$$Y_{it} = \gamma N_{it}^{1-\alpha_i} (Z_{it}(j))^{\theta_i} dj)^{\alpha_i / \theta_i}$$

where $0 < \theta < 1$ and $(\alpha/\theta) > 1$. $Z_{it}(j)$ denotes the quantity of inputs of type j used in the i -th industry.

The resource constraint on inputs used is

$$\int_0^{A_{it}} Z_{it}(j) dj = K_{it}$$

where K_{it} denotes the total amount of capital stocks in the sector. Because all of the different Z_{it} goods are produced according to the same technology (all intermediates are hired in the same magnitude), this sum across different types of goods is reasonable. Given A_{it} , it follows by symmetry that Z_{it} will take on a common value, which implies

$$\overline{Z_{it}} = K_{it} / A_{it}.$$

The production function becomes

$$Y_{it} = \gamma N_{it}^{1-\alpha_i} K_{it}^{\alpha_i} A_{it}^{\alpha_i(1-\theta_i)/\theta_i}$$

Specification of technology above implies increasing returns to specialization in the final goods technology:

$$A_{it}^{\frac{\alpha_i(1-\theta_i)}{\theta_i}} > A_{it}^{\alpha_i}.$$

The growth rate of the i -th industry output is

$$\frac{Y_{it+1}}{Y_{it}} = \exp\left\{\left(\beta_0 + \rho_i \ln Y_{it}\right) \frac{\alpha_i(1-\theta_i)}{\theta_i}\right\} \left(\frac{K_{it+1}}{K_{it}}\right)^{\alpha_i} \left(\frac{N_{it+1}}{N_{it}}\right)^{1-\alpha_i}$$

Equation above can be rewritten as

$$TFPG_{it} = \frac{\alpha_i(1-\theta_i)}{\theta_i} (\beta_0 + \rho_i \ln Y_{it}) = \beta_0 + \rho_i \ln Y_{it} \quad \text{where } i = 1, \dots, I$$

$t = 1, \dots, T,$
.....(21)

where we assume that $\alpha_i(1-\theta_i)=\theta_i$.

When technology is embodied in product varieties, trade in varieties of intermediate inputs and capital goods will result in the expansion of the interval of inputs, A_{it} , and thus in increased output. By importing these specialized inputs, an industry can grow faster. Thus, we would expect that both industry output and trade in these inputs be positively related to an industry's productivity growth. Therefore, (21) can be written as

$$TFPG_{it} = \beta_0_i + \rho_i \ln Y_{it} + \phi_i \ln TI_{it} \text{ where } i = 1, \dots, I \\ t = 1, \dots, T. \dots(22)$$

where TI_{it} denotes the trade index for imported inputs in industry i .

Estimation Methods and Data

Equations (20) and (22) provide the basis for testing the scale hypotheses. The dependent variable is total factor productivity growth (TFPG), familiarly known as the "Solow residual" under perfect competition. The explanatory variable x_{it} is the logarithm of the scale variable implied by each theory. Both estimations have a similar functional form and can be generally expressed as:

$$TFPG_{it} = \beta_0_i + \beta_i' x_{it} + \varepsilon_{it} \text{ where } i = 1, \dots, I \\ t = 1, \dots, T. \dots(23)$$

The intercept term, β_0_i , represents an unobserved industry-specific effect which implies heterogeneity across industries. This industry-specific intercept term may be known by firms in that industry but not by econometricians. If this term is likely to be correlated with the scale variable, it cannot be assumed to be a random variable. This term can be assumed to be fixed over time (or at least over the length of the period of the study). The standard method in panel data analysis is to treat this term as a fixed effect. The error term, ε_{it} , represents the net error measurement that varies across industries and time periods for which the

observations are obtained. We assume that this error term can be characterized by an independently identically distribution (i.i.d.) random variable with mean zero and a variance. The slope coefficient(s), β_i' , is the vector of the estimated impact of the log of scale variable, x_{it} , on industry productivity growth. This β coefficient is assumed to be constant over time, but can be allowed to vary across industries or industrial groups. By allowing β to be different across groups, we do not impose the constraint that the underlying structure is the same for each industry or each industrial group.

In Eq. (23), the industry-specific intercept term is likely to be correlated with the explanatory variables. Ignoring this aspect would lead to inconsistent estimates using the least square method. One possible method to estimate (23) is to include a dummy variable for each industry to account for the fixed effect terms. This method is called the least-square dummy-variable (LSDV) method. The problem with this method is an enormous loss in degrees of freedom. An alternative approach is to use a Within-group estimation (Hsiao 1986). This latter method redefines all the variables as deviations from the mean value for each industry over time. Using this transformation of the data, the industry-specific (and time-specific if included) effects are swept away. In fact, both methods are equivalent and yield the best linear unbiased estimator (BLUE).

At the industry level, we use the Within-estimation method to estimate (23) under two different assumptions. First, by pooling data from different industries, we impose the condition that parameter estimates be the same for each industry. Since this is a standard assumption usually implied by the aggregate growth model, we use this estimation as a base case. The second estimation allows for different estimates across industrial groups. Using this second assumption, we expect that dynamic spillovers from different industrial groups could have different impacts on productivity growth. For example, specialization could have a greater impact on productivity growth in heavy industries than in food and light industries.

Data

To estimate Eqs. (20) and (22), we use manufacturing data sub-sectors at the ISIC-3 digit level during the period between 1951-1995. The manufacturing panel data were

obtained from the National Statistical Office (NSO) in Thailand. They cover 29 three-digit manufacturing industries for certain years from 1970-1994. Three industries (ISIC353, 354, 390) are not included in the analysis due to missing data. The total number of annual data is 15. The total number of observation in full panel analysis is 390.

Our analysis requires data on real output, real value added, capital stock, labor, and material input, share of wage and compensation to labor, and share material costs in total output. All real data are in constant 1972 prices. Total production and total value-added were deflated by the three-digit industry price level at the 1972 prices. These deflators were obtained from the Bank of Thailand quarterly reports. Similarly, the material inputs are deflated by the input price deflators obtained from the Bank of Thailand. Production data is the value of production from the industrial census by the NSO.

The capital stock data from the NSO were available only for certain years. To complete the data set for this variable, we estimate the capital stock using the real net investment data from the NSO, assuming that the depreciation rate is 5 per cent across industries and time. The standard perpetual inventory method is used to calculate this capital stock.

The labor input data is the number of workers employed in that industry during the year. Unfortunately, there are no data based on work-hours and qualifications of workers.

Total factor productivity growth (TFPG) is calculated using a Tornquist index number formula. Details are shown in Appendix A. The shares of labor was calculated by dividing the value of wage and salaries and other compensations by the production value. Similarly, the shares of intermediate inputs was computed by dividing the value of material costs by the production value. The share of capital was the residual.

Table 1 presents the estimated TFPG. Between 1971-1994, average productivity growth was negative for most industrial groups, except light industries. Similar results are obtained when we look at two sub-periods, i.e. 1971-84 and 1985-94. The latter period is concurrent with trade policy reform and declining tariffs on protected industries, particularly import-competing industries. All industrial groups with average negative productivity

growth between 1971-84 experienced even lower productivity growth during the latter period. Heavy industries experienced the highest change in their productivity growth during the period of 1985-94, when their protective barriers have been abolished. Surprisingly, food and related food industries showed a small improvement in their productivity growth during the latter period, when tariff was reduced and trade policy reform was initiated. Since we do not have complete data on protective structure over industries over time, it is difficult to know the relationship between protection and productivity growth. Our data somehow show mixed results about this relationship.

Many scale variables were used in this study: industry value-added, manufacturing value-added, human capital stock at the manufacturing level and industry level, and trade index on imported intermediate and capital goods at the aggregate and industry levels.

Real value-added in manufacturing was obtained from the NESDB. Real value-added at the industry level was from the NSO. Human capital stock at the country level is estimated by the author (Details are provided in Chapter 2 of this report). Due to the lack of data, human capital stock at the industry level is proxied by the ratio of the wage rate in that industry to the average wage rate of all industries. The wage rate in an industry is calculated by dividing the wage and other compensation by the number of employers in that industry. The trade index of specialized inputs at the manufacturing level is proxied by the ratio of imports plus exports to GDP. The trade index of specialized inputs for each industry is calculated by dividing the value of imported intermediate goods and capital goods by real value added in that industry.

It is worth noting that the NSO data on outputs and inputs at the three-digit ISIC level are far from complete. There are many missing data. To fill these missing data, we use information from all other sources that seem appropriate. The sources includes Akrasanee and Wiboonchutikula (1994), Bank of Thailand, and the NESDB data on manufacturing at the 2 digit level. In addition, we imputed output data to make them consistent with the NESDB data in terms of growth rates. Data on inputs were thus adjusted accordingly to the revised data. Table 2 shows how the scale effects implied by each theory varies across manufacturing groups.

Estimation results for Equations (21) and (22) are shown in Table 3. As for the human capital externality theory, the results show that the human capital index, proxied by the wage of that industry relative to average wage, is positively correlated with manufacturing productivity growth in heavy and light manufactures, but is not significantly correlated in skill-intensive and food manufactures. The estimated coefficients imply that a 100-fold increase in the intensity of human capital is associated with a 0.25 % and 0.28 % growth rate in productivity in heavy and light industries, respectively.

For the specialized inputs theory, we regress manufacturing growth rate on the import index and a measure of scale. The import index is a measure of imported intermediate goods and imported capital goods as a fraction of industry output. The scale variable is a measure of manufacturing real value-added. Results reveal a positive correlation between the import index and productivity growth in heavy and light manufactures at a given value added. For a given output, a doubling of the share of imported specialized goods is associated with a 0.07 % and 0.05 % growth rate in productivity in heavy and light industries, respectively. For a given quantity of imported specialized goods, value added is positively correlated with productivity growth--the magnitudes are close to those suggested by learning-by-doing theory. It is worth noting that we use the lagged import index as the instrumental variable for the import index due to its collinearity with manufacturing output. If we do not correct this collinearity problem, the relationship between the import index and manufacturing growth becomes negative, and thus give a spurious result.

In summary, our findings indicate scale effects at the industry level. In each model, the revealed relationship between manufacturing growth and the scale variable varies across industrial groups. The aggregate result is thus an average result among those industrial groups. Human capital externality has a non-negative and significant impact in each industry and thus show a non-negative impact at the aggregate manufacturing level. In all, these results suggest that allowing for different estimates of β yields more information about the underlying relationship between the scale variable and productivity growth.

5. Model Simulation

Since analytical study of the equilibrium is algebraically complex, it may be useful to present the solution of a numerical simulation in order to see how the model works. We want to demonstrate two points. *First*, we will show that for intuitively reasonable parameter values, we can derive situations in which multiple equilibria described in this paper do exist. *Second*, using the hypothetical solution as the starting point, we next ask by how much the degree of human capital externality should be in order to initiate the transition from a low-level to a high-level equilibrium.

The numerical values for the model's parameters are reported in Table 5. To calibrate the model, we work as follows. First, we set some exogenous variables n^f , x^f and $\bar{x}$ to be one by scaling their units of measurements. Next, we move on to the parameters of the CC curve. The degree of industrial backward and forward linkages μ is set equal to 0.45. By construction, this value is amounted to cost share of intermediate sectors and can be obtained by using the 2000 input-output table from the National Economic and Social Development Board (NESDB). The value of manufacturing sector's share γ is set to 0.3 using the national income account from the NESDB. The price elasticity of demand between domestic and imported varieties σ is set equal to 5. The human capital level is assumed to be simply proportional to the number of domestic varieties or firms. We assume that $H=(n^d)^{1/2}$. We finally require parameters of the BB curve. The number of unskilled labor is normalized to one. The equilibrium wage for skilled labor is assumed to be related with the number of domestic varieties. More details for data sources for obtaining parameter values are reported in Appendix 2.

It is important to note that although we use some estimated parameters from real data as a starting point in model simulation. Many of them still are not appropriate to represent the Thai economy. Therefore, interpretations about policy implications from these results should be more cautious.

Figures 4 and 5 show numerical equilibria. Figure 4 illustrates equilibria of the model when there is no human capital externality. On the vertical axis of this figure is the price of domestic intermediate goods p . On the horizontal axis is the number of domestic high-tech

firms n^d . The BB and CC schedules indicate loci along which domestic firms earn zero profits and charge their products according to markup pricing rule. Figure 4 shows that when there is no externality from human capital accumulation, both the CC and BB curves will have a downward slope. There are three equilibria: two stable equilibria and one unstable equilibrium in the middle.

Figure 5 is constructed by allowing for externalities from skilled labor or human capital employed in the manufacturing sector, the situation in which we are interested in. Table 6 reports values of the price of domestic intermediate goods and the number of domestic firms in the high and low-level equilibria in the basic parameterization of the model. By using the parameters in Table 5, two equilibria were found at 6 and 255 respectively. The corresponding numbers of the domestic firms are between 6 and 255. Note that the average firm size is constant in the model and that by chosen units of measurements it is set to be unity. In the high-tech equilibrium, where a large fraction of population chosen to become skilled labor and thus there is a higher level of human capital, the wage rate paid for the skilled labor is more expensive on the margin, so the price of the intermediate goods is higher. Even though the wage for skilled labor is more expensive in this high-level equilibrium, the large number of firms can be sustained because of the positive reinforcing effects that result from externalities from industrial linkages and human capital in the manufacturing.

The presence of the range of the number of firms between 6 and 255 creates possibilities of welfare-enhancing government policy. Large numbers of domestic varieties are required to achieve the new-high tech equilibrium under the model simulation using the recent estimated parameters. It is obvious that if the level of human capital externalities were higher, either in terms on the number or their quality, the expected high-tech equilibrium could have been achieved with the smaller number of domestic industries. Given the slow adjustment in improving the school system in Thailand, other policy leading to an expansion of domestic manufacturing could provide better alternative options for stimulating growth. In particular, as discussed earlier in Punyasavatsut and Coxhead (1999), a government reduction in import tariff on imported intermediate goods can lead the economy to the high-

level equilibrium. Punyasavatsut and Coxhead (1999) demonstrated the effects of tariff reduction to domestic manufacturing industries and industrial equilibrium.⁸

6. Conclusions

This paper has shown a simple general equilibrium model in which industrialization in a small open economy can be triggered by a reduction in the price of intermediate goods. Interactions between externalities that result from human capital accumulation and industrial linkages (in terms of forward and backward linkages) under imperfect competition create the possibility of take-off. Industrialization occurs along with human capital accumulation. The underdevelopment trap is in part due to a coordination failure since these externalities cannot be fully internalized, and there is no sufficient demand for skilled labor.

Some policy implications can be drawn from this model. *First*, in a small open economy, where there is imperfect substitution between domestic and foreign intermediate goods, domestic demand is not entirely irrelevant. The interesting implication of this assumption is that the domestic industry expansion is necessarily for domestic human capital accumulation. And therefore, there is a possibility of increases in human capital stock as the economy more opens to trade. *Second*, an alternative policy to stimulate industrialization is to use a pricing policy, a first-best policy. Tax and subsidy policy on the domestic intermediate goods could do the same task. However, if the foreign intermediate and capital goods are embodied with more advanced technology, there is a limitation in using the first-best policy. Third, interdependence between supplies of intermediate goods and human capital accumulation suggests some government role in coordinating expectations between firms and institutions that supplies higher education. Past experience in shortages of skilled labor during the early of 1990s suggests some existing coordination failure and slow

⁸ Although this numerical exercise is intended to show just a hypothetical case, the results that a tariff reduction stimulates industrial development of the high-tech industries is appealing. Thailand did experience a rapid growth in automobile industries after she continues reductions in tariffs on parts and components, and on domestic content requirement. By all means, other factors also help contributing to the success of automobile manufacturing in Thailand—especially tax exemptions and other investment incentives.

adjustment in market for high skilled labor. Also, if there is some evidence of human capital externality, government subsidy in educational investment will be welfare-improving. However, this study finding indicates the low level of human capital externality in Thailand.

There are obviously many ways in which this analysis could be extended. *First*, if we allow for more complicated labor market dynamics, the set of possible equilibria could be even richer. In our paper, we rely on the naive Marshallian dynamics and the absence of adjustment cost in reallocation of labor from agriculture into manufacturing in deriving the equilibrium outcome. Making the model dynamic can be possible and may yield more interesting aspect of how the equilibrium is selected. As shown in Matsuyama (1991) and Krugman (1991), when the labor reallocation incurs some cost and occurs slowly, this movement should be considered as an investment decision. When their investment decision depends on the current and expected future wage (which depends on the action of other agents), this complementarity will lead to expectational indeterminacy in the perfect foresight model. In this situation, the role of expectation and history can both play an important role in determining the equilibrium outcome. Also, there is a potential role for government policy in coordinating expectations.

Second, our model excludes capital accumulation and mobility. Introducing capital as another ordinary input in the model is obviously a way toward the real world. However, it is less obvious if this will change the outcome: it might not take the economy out of the low-level equilibrium. As argued by Rodriguez-Clare (1996), if capital accumulation is associated with a low number of variety or low division of labor, returns to capital are also small. So, capital does not flow to countries with a poor division of labor. Thus, government intervention to raise the capital accumulation might be able to take the country out of the underdevelopment trap.

Table 1. Summary Statistics of Total Factor Productivity Growth (TFPG) and Input Growth by Industry, Thailand, 1971-1994 (to be cont'd)

ISIC	Industry	Average Growth Rate of				
		TFP (%)	Output (%)	Labor (%)	Materials (%)	Capital (%)
311	Food Products	-0.27	4.31	3.63	5.55	3.67
312	Other food processing	-0.42	11.09	4.80	12.17	5.49
313	Beverage	-2.33	1.56	-2.60	1.34	6.26
314	Tobacco	-2.01	-0.42	-1.00	-0.28	3.70
321	Textiles	-0.62	4.74	2.04	6.64	3.70
322	Wearing apparel, excluding footwear	-1.44	14.96	11.75	17.60	14.30
323	Leather products	-2.43	7.00	7.71	10.53	11.39
324	Footwear	-2.60	10.54	13.32	12.76	13.48
331	Wood Products	-1.84	3.29	2.42	6.59	5.24
332	Furniture	-2.91	3.14	4.98	6.05	6.92
341	Paper and paper products	0.62	9.03	6.70	9.97	5.48
342	Printing and publishing	11.09	17.66	13.03	5.47	4.38
351	Basic Chemicals	3.71	2.10	-1.86	-3.12	4.28
352	Chemical products	-1.77	2.90	-0.03	4.00	4.89
355	Rubber and rubber products	-3.50	5.72	4.66	8.41	8.26
356	Plastic products	2.91	16.52	17.93	15.91	12.05
361	Manufacture of pottery	2.38	12.39	7.85	13.63	6.37
362	Glass and glass products	-2.23	2.92	1.96	4.79	4.35
369	Other non-metallic mineral products	-2.18	7.68	4.72	9.81	9.85
371	Iron and steel	-0.96	17.81	11.34	17.84	22.44
372	Non-ferrous metal products	-7.22	12.92	10.74	19.16	11.72
381	Metal products	-2.14	1.64	3.70	3.20	4.96
382	Non-electrical machinery	-2.49	8.29	6.16	10.95	10.47
383	Electrical machinery	1.65	5.79	2.46	7.41	2.12
384	Transport equipments	-1.91	5.19	4.10	5.72	9.09
385	Professional and scientific equipment	0.05	12.20	7.82	14.48	8.13

Source: Author's Calculation.

Table 1 (Cont'd) Summary Statistics of Total Factor Productivity Growth (TFPG) by Sub-periods.

ISIC code	Industry	Average TFPG (%)		
		1971-94	1971-84	1985-94
311	Food Products	-0.27	0.42	-1.05
312	Other food processing	-0.42	-0.33	-0.52
313	Beverage	-2.33	-3.28	-1.24
314	Tobacco	-2.01	-2.23	-1.75
322	Wearing apparel, excluding footwear	-1.44	-1.64	-1.21
323	Leather products	-2.43	0.86	-6.20
324	Footwear	-2.60	-1.55	-3.80
331	Wood Products	-1.84	-1.42	-2.33
332	Furniture	-2.91	-1.22	-4.85
341	Paper and paper products	0.62	1.41	-0.28
342	Printing and publishing	11.09	5.73	17.21
321	Textiles	-0.62	0.93	-2.38
351	Basic Chemicals	3.71	7.41	-0.51
352	Chemical products	-1.77	-1.11	-2.53
355	Rubber and rubber products	-3.50	-4.95	-1.85
356	Plastic products	2.91	6.70	-1.41
361	Manufacture of pottery	2.38	3.53	1.11
362	Glass and glass products	-2.23	-3.98	-0.23
369	Other non-metallic mineral products	-2.18	-1.69	-2.75
371	Iron and steel	-0.96	-0.05	-2.01
372	Non-ferrous metal products	-7.22	-10.66	-3.30
381	Metal products	-2.14	-4.41	0.47
382	Non-electrical machinery	-2.49	-1.37	-3.77
383	Electrical machinery	1.65	3.43	-0.38
384	Transport equipments	-1.91	-1.72	-2.14
385	Professional and scientific equipment	0.05	-0.67	0.86
	Heavy Industries	-0.94	-0.35	-1.63
	Skill-labor Industries	-1.00	-0.98	-1.04
	Light Industries	0.35	0.47	0.23
	Food and related Industries	-1.24	-1.35	-1.13

Source: Author's Calculation.

Table 2. Summary Statistics for Scale Variables

ISIC code	Industry	Scale Variable (in log)					
		real value added		Human capital index		Import Index	
		Mean	Std Dev.	Mean	Std Dev.	Mean	Std Dev.
311	Food Products	17.51	0.78	-0.14	0.19	-0.32	0.07
312	Other food processing	15.18	1.48	-0.14	0.19	-0.25	0.09
313	Beverage	16.67	0.76	0.37	0.36	-1.23	0.16
314	Tobacco	14.83	2.54	-0.10	1.00	-0.60	0.08
321	Textiles	17.33	0.86	-0.27	0.16	-0.47	0.11
322	Wearing apparel, excluding footwear	15.07	2.26	-0.43	0.35	-0.38	0.08
323	Leather products	13.54	1.06	-0.16	0.40	-0.44	0.07
324	Footwear	11.69	2.54	-0.51	0.45	-0.52	0.10
331	Wood Products	14.70	0.29	-0.36	0.20	-0.48	0.13
332	Furniture	13.07	1.26	-0.29	0.47	-0.48	0.08
341	Paper and paper products	15.25	1.22	0.13	0.25	-0.36	0.07
342	Printing and publishing	15.78	1.44	0.16	0.33	-0.72	0.60
351	Basic Chemicals	15.50	1.34	0.25	0.41	-0.43	0.05
352	Chemical products	15.98	0.75	0.27	0.27	-0.42	0.17
355	Rubber and rubber products	15.99	1.13	0.05	0.32	-0.37	0.11
356	Plastic products	14.33	1.79	-0.29	0.35	-0.47	0.20
361	Manufacture of pottery	12.62	1.19	-0.76	0.29	-0.77	0.12
362	Glass and glass products	14.27	0.53	0.42	0.40	-0.72	0.13
369	Other non-metallic mineral products	16.07	0.97	0.53	0.23	-0.50	0.13
371	Iron and steel	14.64	2.26	0.09	0.52	-0.37	0.14
372	Non-ferrous metal products	12.93	1.24	-0.46	0.21	-0.23	0.14
381	Metal products	15.61	0.77	-0.10	0.24	-0.39	0.09
382	Non-electrical machinery	14.75	1.51	-0.08	0.37	-0.40	0.08
383	Electrical machinery	15.72	1.36	0.04	0.30	-0.42	0.10
384	Transport equipments	16.02	1.18	0.32	0.19	-0.40	0.09
385	Professional and scientific equipment	12.01	1.85	-0.26	0.61	-0.44	0.07

Source: Author's Calculation.

Table 3. Regression Results at the Industry Level by the Within-group Estimation, 1970-94.

Model	Scale variable	Trade Index variable	Scale coef.	Trade coef.	R-squared
<u>Human capital externality</u>	index of human capital		-0.0147 (0.016)		0.06
<u>Specialized inputs</u>	real manuf. value added	share of imported capital and intermediate goods	0.005 (0.004)	-0.09 (0.04)	0.08

Source: Author's calculation.

Note: Numbers in parentheses are standard errors. The number of observation is 390.

Table 4. Regression Results at the Industry Level by Industrial Groups

Group	Human capital externality		
	scale coef.	R-squared	no. of obs.
Heavy Industries	0.056 * (0.02)	0.03	150
Skill-labor intensive Industries	0.01 (0.03)	0.01	75
Light Industries	0.061 * (0.023)	0.05	105
Food and other Industries	-0.036 (0.026)	0.03	60
Group	Specialized inputs		
	scale coef.	trade coef.	R-squared
Heavy Industries	0.008 * (0.005)	0.107 * (0.05)	0.04
Skill-labor intensive Industries	0.008 (0.009)	0.133 (0.009)	0.03
Light Industries	0.011 (0.009)	0.075 * (0.035)	0.05
Food and other Industries	-0.014 * (0.008)	0.117 (0.009)	0.1

Source: Author's Calculation.

Notes:

-* and ** mean significance level at the 5 % level, respectively.

- Numbers in parentheses are standard errors.

Table 5. Parameter Values (Base Model Calibration)

Parameter	Value	Description
$\mu > 0$	0.67	Degree of linkages
$\gamma > 0$	0.28	Share of manufacturing sector in GDP
$\sigma > 1$	5	Demand Price Elasticity of Substitution between domestic and imported varieties
λ	0.09	Human capital externality
H	$= (n^d)^{1/2}$	Skilled labor or human capital
W_H	3	Wage for skilled labor
W_L	1	Wage for unskilled labor
$\bar{x}$	1	Average domestic firm size
n^f	1	The number of foreign varieties
p^f	1	Price for foreign intermediates
x^f	1	Foreign firm size.

Source: See Appendix B.

Table 6. Numerical Values of the Price of Domestic Intermediate Goods and the Number of Domestic Firms in the High and Low-level Equilibriums.

	prices of domestic intermediate goods	the number of domestic firms
Low-tech equilibrium	1.7	6
High-tech equilibrium	7.5	255

Source: Author's calculation.

Figure 1. Multiple Equilibria

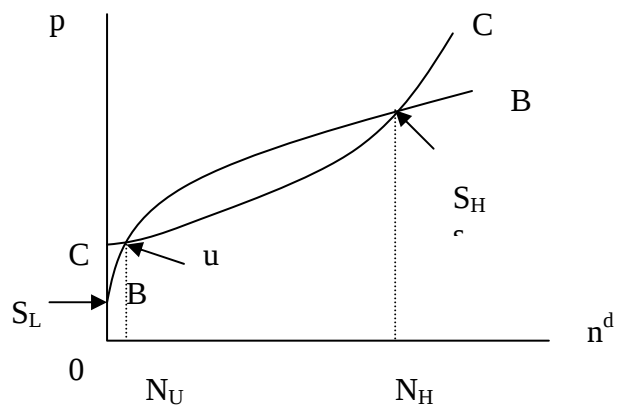


Figure 2. A Tariff Reduction Triggers Industrialization when Human Capital Externality is Strong.

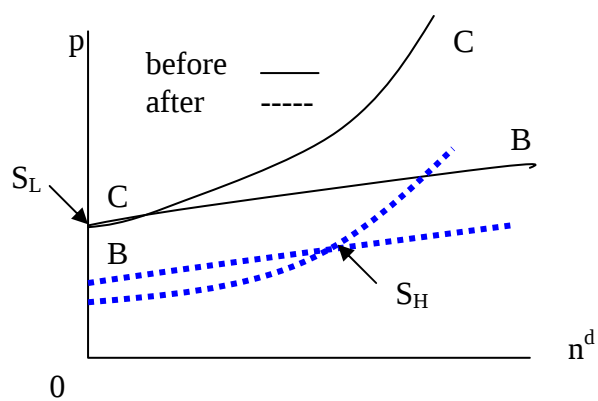


Figure 3. A Tariff Reduction Triggers Industrialization when there is no human Capital Externality.

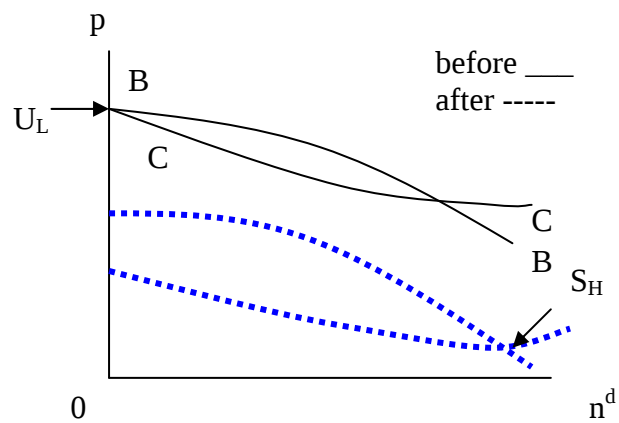
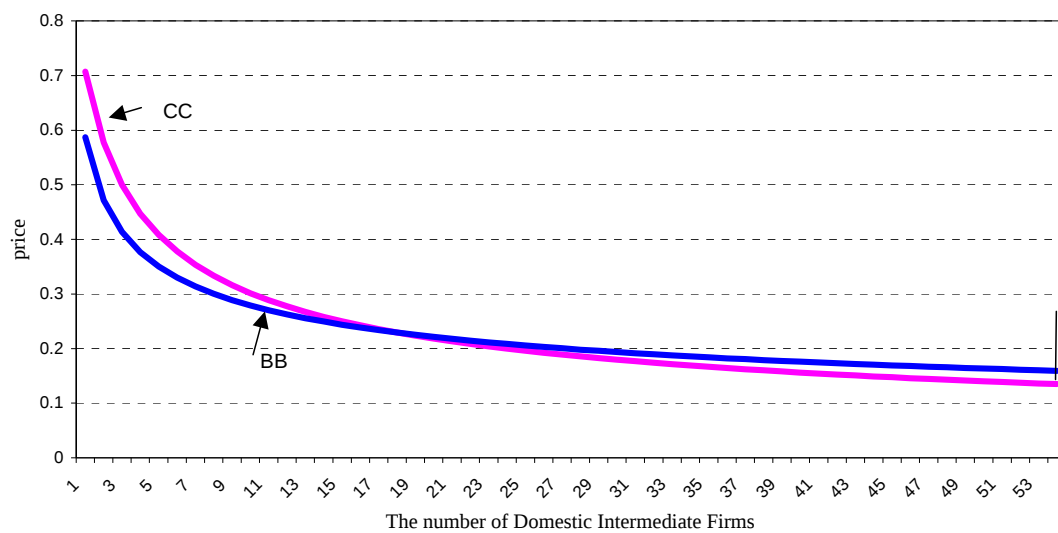
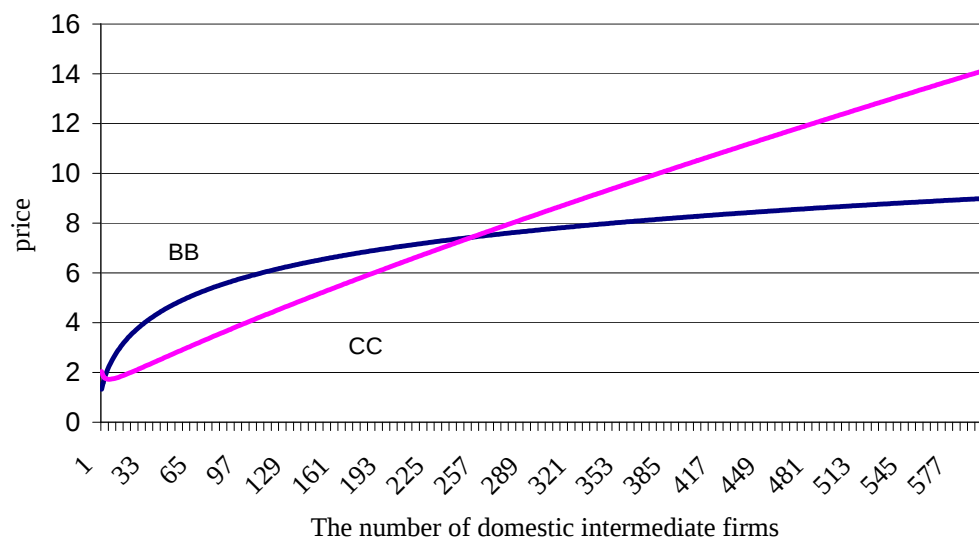


Figure 4. Numerical Equilibria when There is No Human Capital Externality



Note: See parameter values in Appendix B.

Figure 5. Numerical Equilibria when There Is Human Capital Externality



Note: See parameter values in Appendix B.

Appendix A. Measurement of the Total Factor Productivity Growth (TFPG)

The total factor productivity growth (TFPG) can be measured in a number of different ways. One standard approach is to use the Tornquist index number formula, which is a discrete approximation to the formula used here.

$$TFPG_{it} = [\ln Y_{it} - \ln Y_{it-1}] - (1 - \alpha_i)[(\ln K_{it} - \ln K_{it-1})] \\ - \alpha_i[(\ln N_{it} - \ln N_{it-1})]$$
$$where \alpha_i = \frac{1}{2}[\alpha_{it} + \alpha_{it-1}].$$

where

Y_{it} is the value added of the i-th industry in period t,

K_{it} is the capital stock in the i-th industry in period t,,

N_{it} is the labor employed in the i-th industry in period t,

α_{it} is the labor income share in the ith- industry in period t.

Appendix B. Source for Parameter Values in Model Simulation

Parameter	Description	Sources
$\mu > 0$	Degree of linkages	2000 Input-Output Table from the National Statistics Office
$\gamma > 0$	Share of manufacturing sector in GDP	National Income Account from the National Economic and Social Development Board. The value is as of 1995.
$\sigma > 1$	Demand Price Elasticity of Substitution between domestic and imported varieties	Since we cannot obtain this estimate from Thai data, we use the same value as used in Krugman and Venables (1995) which set this parameter equal to 5.
λ	Human capital externality	The degree of human capital externality can be calculated from $0.05 / (1 - \text{capital income share})$. The average value of capital income share during 2000-2004 is 0.44. The numerator is the estimated coefficient from Table 4 of this paper.
H	Skilled labor or human capital	Supply of skilled labor in equilibrium is assumed to be a proportional to the number of domestic firms.

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