Discovering the Sources of TFP Growth: Occupation Choice, Capital Heterogeneity, and Financial Deepening

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Abstract

The sources of "total factor productivity (TFP) growth" or the "Solow residual" typically remain unknown as a *residual*. This paper aims to identify the underlying sources of this residual growth, being explicit about micro underpinnings and transitional growth from occupation choices of heterogeneous agents and financial deepening in use of both macro and micro data. We develop a method of growth accounting that decomposes not only the overall growth but also the residual TFP growth into four components: occupational shifts, financial deepening, capital heterogeneity, and sectoral Solow residuals. Applying this method to Thailand, which experienced rapid growth with enormous structural changes for the two decades between 1976 and 1996, we find that 55 percent of TFP growth can be explained on average by occupational shifts and financial deepening, without presuming exogenous technical progress. Expansion of credit is a major part of this explained TFP growth. Decomposition of the simulation helps us to infer that for the remainder TFP growth, capital-heterogeneity effect is behind during the initial period (1976-1980) while sectoral Solow residuals, due to the surge of wage after 1986, is behind during the latter decade (1986-1996).

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1 Introduction

Total factor productivity (TFP) growth is measured as a residual, total output growth less the weighted sum of input growth. It is also called the "Solow residual." By definition, this residual growth measures the improvement of productivity in a Hicks-neutral *aggregate production function*. However, the improvement of *aggregate efficiency* measured in this way can come from various sources, which typically remain unknown inside the *residual*. As Abramovitz (1956) puts it, the Solow residual represents a "measure of our ignorance" of growth process.

This paper aims to identify the underlying sources of the residual growth via an integrated use of models and data. We use a growth model that makes explicit its micro underpinnings, namely occupation choices and limited access to credit, and features transition, and we then propose a growth accounting method based on the model. This allows us to decompose not only the total output growth into the factor accumulation and the TFP growth but also to further decompose the TFP growth into its underlying sources, combining micro data with macro data. The growth accounting method is applied to Thailand, where rapid economic growth was accompanied by enormous structural changes for the two decades between 1976 and 1996. From the theory-data

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nexus and micro-macro data synthesis, we find various sources of TFP growth, in particular the importance of financial deepening.

Jorgenson and Griliches (1967) suggest that *careful measurement* and *correct model specification* would weed out the "errors," i.e., the "measure of our ignorance." Their accompanied empirical work successfully showed that careful measurement of education and capital utilization curtails the size of the residual. Still, although smaller, the residual turned out to remain the major part.[1] Most of the subsequent empirical work focuses on careful measurement of input variables (mainly by refining the concept of capital) rather than on correct model specification, and this continues to confirm the substantial size of the residual in most countries.[2] Klenow and Rodríguez-Clare (1997) and Prescott (1998) succinctly argue that it is TFP rather than capital that determines the levels and changes in international income differences even if the concept of capital is broadened to include intangible capital such as human capital and organization capital. From the series of depression studies for nine advanced countries, and a study for U.S. by Cole and Ohanian (1999), Kehoe and Prescott (2002) conclude that the changes in TFP are crucial also in accounting for the within-country business fluctuation.[3]

The basis of these studies is the neoclassical growth model built on an aggregate production function with exogenous technical change. Solow (1957) himself emphasized that he used the phrase "technical change" for any kinds of shift in the production function. In particular, when an economy is engaged in a structural transformation, compositional changes among sectors or activities, across which productivity levels differ on the extensive margins, would not only contribute to output growth but also to productivity growth without any true technical change. The documentation of the empirical importance of the structural change on economic growth dates at least back to Clark (1940) and Kuznets (1957). The emphasis on the theoretical importance of transition in understanding the true dynamics of growth and development was made early by Hicks (1965) and Schultz (1990), and recently reaffirmed by Lucas (2002).[4] Hansen and Prescott (2002), and Gollin, Parente, and Rogerson (2001) illustrate that incorporating structural transformation helps to explain the long term growth path and evolution of the international differences in per capita income. However, these models are again built on exogenous technical progress at the sectoral level, and the aggregate residual is simply decomposed into

[1] The portion of the residual for the U.S. growth during the 1950-1962 period went down to 54%, which is a much smaller number than the original estimates, 86% by Abramovitz (1956), or 88% by Solow (1957). But it is still the major source. In fact, Jorgenson and Griliches (1967) reduced to the portion to 5% in their original paper, but corrected to 54% upon the criticism of Denison (1969) on their excessively wide adjustment in capital utilization.

[2] See Griliches (2000) and Hulten (2001) for excellent summaries of the empirical history of the residual.

[3] The nine coutries include Canada, France, Germany, Italy, and the U.K. in the interwar period, and Argentina, Chile, and Mexico in the 1980's, and Japan in the 1990's. France, Italy, and the U.K are exceptional examples. See the 2002 special volume of *Review of Economic Dynamics* V. 5, No. 1, for details.

[4] Hicks (1965) argues that the *speed* of convergence does matter in order to consider the balanced-growth-path as a valid description of actual growth path. Schultz (1990) emphasizes the importance of the process of restoring equilibria in transition in the course of economic growth. Lucas (2002) asserts that "a useful theory of economic development will necessarily be a theory of transition."

sectoral residuals.

The fundamental idea of Jorgenson and Griliches (1967) is that productivity growth should be *explained* rather than just measured, and *both* measurement and theory are crucial in doing so. Some existing studies such as the depression studies in Kehoe and Prescott (2002) indeed pursue a tight link between the theory and the data, as we do in this paper. They do successfully identify the importance of the TFP itself. However, regarding the identification of the *sources* of the TFP growth, they either direct the reader to future research or postulate policy-oriented conjectures based on informed guess. As Kehoe and Prescott (2002) conclude, "absent careful micro studies at firm and industry levels, we can only conjecture as to what these policies are," calling for micro evidence. In this paper, we are explicit about the micro underpinnings of the growth model, and we attempt not only to integrate the model and the data, but also to use both the micro data and the macro data in a synthetic way to fill this gap.

We consider a growth model that has two different kinds of technology, traditional and modern. This has deep roots in the development literature such as in Lewis (1954) and Ranis and Fei (1961). Only the modern technology uses hired labor and capital while the traditional technology provides fixed subsistence income using self-employed labor alone. The occupational choices and the accompanied choice of technology are based on presumed differentials in entrepreneurial talents in the population. However, for agents who do not have access to credit, occupational choices are subject to an additional constraint, individual wealth, as in Lloyd-Ellis and Bernhardt (2000) and Banerjee and Newman (1993). In contrast, occupational choices in the financial sector depend only on the talent. In sum, the technological blue prints are commonly available to everyone, but only subset of agents adopt the modern technology due to the two kinds of heterogeneity, i.e., wealth and talent. In this model, productivity depends on efficiency in allocation of the talent and the capital, both of which improve as the financial sector expands. Specifically, the expansion affects the occupational choice in the entire population (extensive margin) and also the efficiency of using capital among the entrepreneurs (intensive margin).

We intentionally shut down all exogenous technological change, the typical engine of productivity growth in the existing TFP literature. Thus, productivity growth cannot come from technical change but only from improving allocation efficiency, which depends on financial deepening. This is not because we think technical change is unimportant, but rather we would like to see how well the alternative hypothesis based on occupational transition and financial deepening can explain the actual growth of output and TFP.

The relationship between financial development and economic growth was postulated early by Schumpeter (1911) and its empirical patterns were addressed early also by Goldsmith (1969) and McKinnon (1973). Recent theoretical underpinnings of the relationship have been developed, e.g., by Greenwood and Jovanovic (1990), and Bencivenga and Smith (1991) and recent empirical evidence has been provided by Townsend (1983), King and Levine (1993) and Levine and Zervos (1998) using cross-country data, and by Rajan and Zingales (1998) using the industry-level data across countries. In particular, Beck, Levine, and Loayza (2000) find that the positive effect of financial intermediation on GDP growth is through its impact on TFP growth rather than through its impact on physical capital accumulation and private savings rates. None of them, however, bring a structural model to the data. Our integrated use of the model and the data provides more direct evidence on the finance-growth relationship.

The paper is organized as follows. Section 2 describes the model economy. Section 3 reviews and further develops a method of growth accounting, explaining how the residual TFP growth can be further decomposed. In Section 4, the data sources are described and *standard* growth accounting is done. In Section 5, the Thai data are brought into to calibrate the model. We simulate the Thai economy from the model, and the simulated economy is decomposed following the growth accounting method of Section 3. Sensitivity analysis is also conducted. In Section 6, we bring the model back to the micro data and decompose the actual Thai TFP growth. We thus combine our results with those from the macro growth accounting to identify the sources and patterns of the economic growth in Thailand. Section 7 concludes.

2 Model

We consider a model of wealth-constrained occupation choice as in Lloyd-Ellis and Bernhardt (LEB) (2000), but allow a credit market for a limited group of agents. The economy is populated by a continuum of agents with measure one evolving over discrete time $t = 0, 1, 2....$ An agent i with end-of-period wealth W_{it} at date t maximizes preferences over a single consumption good c_{it} and wealth carry-over $b_{i,t+1}$ as represented by the utility function

$$u(c_{it}, b_{i,t+1}) = c_{it}^{1-\varpi} b_{i,t+1}^{\varpi}$$

subject to the budget constraint $c_{it} + b_{i,t+1} = W_{it}$.[5] Each agent is endowed with a single unit of time.

There are two kinds of production technology, traditional and modern. In traditional technology, everyone earns a subsistence return γ of the single consumption good. In modern technology, entrepreneurs hire capital k_t

[5]This Cobb-Douglas form of preferences implies a linear rule of savings behavior, which simplifies the dynamics of the model.

and labor l_t at each date t to produce the single consumption good according to quadratic production function[6]

$$f(k_t, l_t) = \alpha k_t - \frac{\beta}{2} k_t^2 + \xi l_t - \frac{\rho}{2} l_t^2 + \sigma l_t k_t. \tag{1}$$

Thus, there are two occupations (entrepreneurs and wageworkers) in modern technology and only one occupation (self-employed subsisters) in traditional technology. The single unit of time is inelastically supplied to the devoted occupation he chooses, which determines individual income: profits for modern entrepreneurs, wages for wageworkers, and the subsistence return for traditional self-employed.

There exists an initial setup cost x_{it} to start up a business, which represents the inverse of the innate entrepreneurial talent of each agent. This is assumed to be independent of the initial wealth level b_{it} and randomly drawn from a time-invariant *i.i.d.* uniform distribution over a unit interval $[0, 1]$

$$H(x_{it}) = x_{it}.$$

In this model, an agent i is distinguished by a pair of beginning-of-period characteristics: initial wealth b_i and randomly drawn entrepreneurial (lack of) talent x_i. (Hereafter, due to the recurrent nature of the model, the time subscript is tuned off unless it is necessary to make it explicit.) With the above utility function, the optimal rules for consumption and saving are linear functions of wealth, and so preference maximization is equivalent to end-of-period wealth maximization. Thus, given equilibrium prices, the wage w and the gross interest (or shadow price for storage) r, an agent of type (b_i, x_i) chooses his occupation to maximize his total wealth W_i:

$$\begin{aligned} W_i &= \gamma + r b_i \text{ for traditional subsisters,} \qquad (2) \\ &= w + r b_i \text{ for wage laborers,} \\ &= \pi(b_i, x_i, w) + r b_i, \text{ for entrepreneurs,} \end{aligned}$$

where

$$\pi(b_i, x_i, w) = \max_{k_i, l_i} \{ f(k_i, l_i) - w l_i - r k_i - x_i \} \tag{3}$$

Equation (2) suggests that there is a reservation wage level $\underline{w} = \gamma$ below which every potential wageworker prefers to remain in traditional technology. Likewise, if the wage rate exceeds that reservation wage, no one

[6]The conventional specification of technology for neoclassical growth models is Cobb-Douglas, which imposes unit elasticity of substitution between factors, and hence constant factor shares, regardless of the level of input. Although there are some empirical studies justifying the constant factor shares at aggregate level, it is only *roughly* true. It is technology rather than preferences that puts important restrictions on the TFP analysis. The quadratic technology adopted here is more flexible than the Cobb-Douglas technology, allowing time-varying factor shares and imposing no restriction on returns to scale, and is one of the most parsimonious general specifications with two production factors.

In specific, Fuss, McFadden, and Mundlak (1978) show that the required number of parameters to represent a technology in the absence of homogeneity restrictions with n factors is $(n+1)(n+2)/2$, and generalized Leontief, translog, and quadratic forms satisfy this requirement. With dichotomous factors, capital and labor, we need six parameters. Here, we normalize the constant parameter of the quadratic form as zero, which does not matter for *growth* accounting.

remains in traditional technology. Therefore, when the traditional technology coexists with the modern technology, the equilibrium wage is tied to the subsistence income γ, and the population proportions of wage earners and subsistence self-employed are determined only by the demand for labor from the modern technology. This resembles the feature of Lewis's (1954) well-known model of unlimited labor supply in a dual economy. The equilibrium wage starts to grow, being determined by marginal productivity of labor, after some critical point, as Ranis and Fei (1961) call it a "commercialization point."

Suppose now as in LEB that there is a first sector with no credit market. Then, the cost of capital is determined by its opportunity cost, a constant interest rate of unity tied to a backyard technology, i.e., $r = 1$, and firms should self-finance and face the following borrowing constraint:

$$0 \leq k_i \leq b_i - x_i. \tag{4}$$

The higher is the initial wealth b_i, the more likely it is that an agent will be an entrepreneur. A potentially efficient, low x_i, agent may end up being a wageworker, constrained by low initial wealth b_i. Given wealth b_i and market wage w, we can define a marginal agent as one with setup cost $x^m(b_i, w)$ who is indifferent between being a worker and being an entrepreneur, that is $\pi(b_i, x^m, w) = w$. If the setup cost is higher than x^m, the household will be a worker for sure. However, with the borrowing constraint in (4), the setup cost x_i cannot exceed his own wealth b_i either. Therefore, given wage w and wealth b_i, the critical setup cost for the marginal agent is characterized:

$$z(b_i, w) = \min \left[b_i, x^m(b_i, w) \right]. \tag{5}$$

With setup cost less than $z(b_i, w)$, the household chooses to be an entrepreneur, earning profits higher than wages. Profits are thus the returns to heterogeneous talents. This selection feature yields non-zero profits and makes the typical constant-returns-to-scale (CRS) framework of growth accounting (i.e., zero profits) break down.

The quadratic form of technology in (1) implies that labor demand l_i is linear in capital demand k_i

$$l_i = \frac{\xi - w}{\rho} + \frac{\sigma}{\rho} k_i \tag{6}$$

and profit function becomes a second-degree polynomial in capital k_i:

$$\pi(b_i, x_i, w) = C_0(w) + C_1(w) k_i + C_2 k_i^2 - x_i, \tag{7}$$

where

$$
\begin{aligned}
C_0(w) &= \frac{(\xi - w)^2}{2\rho}, &(8)\\
C_1(w) &= \alpha - 1 + \frac{\sigma(\xi - w)}{\rho}, &(9)\\
C_2 &= \frac{1}{2}(\frac{\sigma^2}{\rho} - \beta). &(10)
\end{aligned}
$$

Capital demand k_i depends on wealth b_i when the borrowing constraint binds, i.e., $k_i = b_i - x_i$. For the unconstrained entrepreneurs, the optimal capital demand k_1^* is given by

$$
k_1^* = \max\{\frac{C_1(w)}{-2C_2}, 0\},
$$

which does not depend on wealth, and hence neither does the profit.

The critical setup cost function $z(b, w)$ can be characterized by the coefficients of the profit function:

$$
\begin{aligned}
z(b, w) &= x^*(w),\ if\ b \geq b^*(w) &(11)\\
&= b + \frac{C_1(w) + 1 - \sqrt{(C_1(w) + 1)^2 - 4C_2\,(C_0(w) - b - w)}}{2C_2},\ if\ \widehat{b}(w) \leq b < b^*(w)\\
&= b,\ if\ b < \widehat{b}(w),
\end{aligned}
$$

where

$$
\begin{aligned}
\widehat{b}(w) &= C_0(w) - w, &(12)\\
x^*(w) &= \widehat{b}(w) - \frac{C_1(w)^2}{4C_2}, &(13)\\
b^*(w) &= x^*(w) - \frac{C_1(w)}{2C_2}. &(14)
\end{aligned}
$$

The $b^*(w)$ is the critical level of wealth above which the wealth constraint does not bind in occupation choice, $x^*(w)$ is the associated level of critical setup cost, and $\widehat{b}(w)$ is the wealth level below which the wealth constraint binds exactly at the level of setup cost ($x_i = b_i$) and hence the capital demand k_i hits the lower bound zero.

Now suppose that there is a second sector with a credit market for borrowing and saving. Then, the borrowing constraint (4) drops, and the cost of capital is an equilibrium interest rate $r \geq 1$ that equates the supply and the demand for capital in the credit market. The capital demand k_2^* of the second sector is given by

$$
k_2^* = \max\{\frac{\rho(\alpha - r) + \sigma(\xi - w)}{\rho\beta - \sigma^2}, 0\},
$$

and the labor demand l_2^* by

$$
l_2^* = \frac{\xi - w}{\rho} + \frac{\sigma}{\rho} k_2^*.
$$

Occupation choice in the credit sector is entirely determined by talent and not by individual wealth, where the critical setup cost $x_2^*(w,r)$ in credit sector can be found by equating the unconstrained profit with wage, i.e.,

$$x_2^*(w,r) = f(k_2^*, l_2^*) - wl_2^* - rk_2^* - w. \tag{15}$$

An entrepreneur, whose setup cost x_i is less than $x_2^*(w,r)$, will establish a modern firm and earn optimal profits

$$\pi_2^*(x_i, w, r) = f(k_2^*(w,r), l_2^*(w,r)) - wl_2^*(w,r) - rk_2^*(w,r) - x_i. \tag{16}$$

Note that, unlike the first non-intermediated sector, the firm size in the intermediated sector is constant, measured by either capital or labor, across firms, and the differential profit comes only through differences in individual talents, i.e., the setup cost x_i. Also the Envelope theorem suggests that the profit in the credit sector should decrease when the factor prices of wage and interest rates increase.

We combine the two sectors in one model with an exogenously expanding intermediated sector mimicking the Thai SES data.[7] In this model, there are two extensive margins, different occupations and different access to credit, which create the productivity differential. The same one unit of time endowment can be devoted to different types of income-generating activities depending on occupation choice. This creates heterogeneous returns to the same time endowment as long as there exist occupational income gaps. Thus, occupational shift from the traditional subsisters and laborers to the entrepreneurs enhances the productivity of the economy. In the credit sector, this occupational shift is easier than in the non-credit sector, because the access to credit relaxes the borrowing constraint in occupational choice. Thus, financial deepening indirectly contributes to productivity growth through this channel, extending the extensive margin. Access to credit helps to improve the productivity via another route. In the credit sector, capital is used more efficiently on the intensive margin among entrepreneurs yielding more profit than in the non-credit sector. This gap in profitability between the two sectors creates a source of productivity growth from financial deepening.

In sum, households of varying talent face an imperfect credit market in financing the establishment of business and in expanding the scale of enterprise. Thus, households are constrained by limited wealth on an extensive margin of occupation choice and an intensive margin of capital utilized, though both constraints can be alleviated over time as wealth accumulates. The pure occupational shift with given level of financial deepening can be another source of productivity growth. Financial deepening relaxes borrowing constraints both on the extensive and intensive margins and enhances the productivity of the economy. Thus, as the distribution of wealth evolves and financial sector deepens, so does the occupational composition of population and the allocation efficiency, generating the dynamics of aggregate output and productivity growth.

[7] Financial deepening may well be endogenous as in Greenwood and Jovanovic (1990). Here, we just impose the participation decision in the financial sector *as in the data*, hoping that we take a fair footing with the typical TFP literature, where the main engine of growth, i.e., technical changes, is assumed to be exogenous. Jeong and Townsend (2003) indeed evaluate the Greenwood and Jovanovic (1990) model, discussing the pros and cons of endogenizing the participation decision in the financial sector, in comparison with our current model of endogenous occupation choice with exogenous financial deepening.

3 Method of Growth Accounting

3.1 Aggregation of Two-Sector Economy

We develop a method of growth accounting that is adapted to the above two-sector three-occupation model. There are two sectors, one without access to credit (sector 1) and the other with access to credit (sector 2). The three occupations are self-employed subsisters using traditional technology, wageworkers, and entrepreneurs using modern technology. The labor market is integrated and wage rate w is common between two sectors. However, the capital market is exogenously segmented, where the opportunity cost of capital differs between two sectors: it is unity, tied to the backyard technology, in sector 1, but it is the equilibrium interest rate r of the credit market in sector 2. Owing to the exogenously embedded segmentation, we can derive the aggregate relationships within each sector separately and then add them up to get economy-wide aggregate relationship.

3.1.1 Aggregation Within Sectors

Given equilibrium wage rate w, the profit π_{i1} of an agent i with setup cost x_i and wealth b_i who chooses to be an entrepreneur (or a modern firm) in sector 1 is given by:

$$\begin{aligned} \pi_{i1} &= \pi_1(b_i, x_i, w) \\ &= f(l_{i1}, k_{i1}) - wl_{i1} - k_{i1} - x_i, \end{aligned} \tag{17}$$

where l_{i1} and k_{i1} denote optimal demands for labor and capital, respectively:

$$\begin{aligned} l_{i1} &= l_1(b_i, x_i, w), \\ k_{i1} &= k_1(b_i, x_i, w). \end{aligned}$$

Thus, the output y_{i1}^m of the modern firm i in sector 1 by simply rearranging (17) can be expressed:

$$\begin{aligned} y_{i1}^m &= f(l_{i1}, k_{i1}) \\ &= \pi_1(b_i, x_i, w) + wl_1(b_i, x_i, w) + k_1(b_i, x_i, w) + x_i, \end{aligned}$$

and the total output Y_1^m of all modern firms in sector 1 is given by:

$$Y_1^m = \Pi_1 + wL_1^m + K_1^m + X_1, \tag{18}$$

defining

$$
\begin{aligned}
\Pi_1 &= \int_0^\infty \int_0^{z(b,w)} \pi_1(b,x,w) dH(x) d\Psi_1(b), \\
L_1^m &= \int_0^\infty \int_0^{z(b,w)} l_1(b,x,w) dH(x) d\Psi_1(b), \\
K_1^m &= \int_0^\infty \int_0^{z(b,w)} k_1(b,x,w) dH(x) d\Psi_1(b), \\
X_1 &= \int_0^{z(b,w)} x dH(x),
\end{aligned}
$$

where $z(b,w)$ is given in (11), Ψ_1 denotes cumulative distribution function of wealth in sector 1 (which endogenously evolves over time), and H the time-invariant distribution function of setup cost. Equation (18) indicates that the output produced in sector 1 is decomposed into profits Π_1, wage payment wL_1^m, contribution of working capital K_1^m, and the contribution of setup-cost capital X_1. Note that depreciation of capital is not incorporated here, as in the model. Also note the explicit inclusion of setup cost, which is not typical in standard income accounting.

The population in sector 1 is partitioned into three occupations, the fractions of which are given:

$$
\begin{aligned}
\Phi_1^e &= \int_0^\infty \int_0^{z(b,w)} dH(x) d\Psi_1(b) \text{ for entrepreneurs,} \\
\Phi_1^w &= L_1^m \text{ for wage laborers,} \\
\Phi_1^s &= 1 - \Phi_1^e - \Phi_1^w \text{ for traditional subsisters.}
\end{aligned}
$$

Thus, total output from traditional technology in sector 1 is

$$Y_1^s = \Phi_1^s \gamma. \tag{19}$$

Let K_1 denote the total wealth in sector 1. Wealth that is not used for modern production, $K_1 - K_1^m - X_1$ is invested in the backyard storage technology and produces output Y_1^b with the rate of return of unity:

$$Y_1^b = K_1 - K_1^m - X_1. \tag{20}$$

Combining these three sources of output production in (18), (19), and (20), we get the total output in sector 1, Y_1:

$$
\begin{aligned}
Y_1 &= Y_1^m + Y_1^s + Y_1^b \\
&= \Pi_1 + wL_1^m + K_1^m + X_1 + \Phi_1^s\gamma + K_1 - K_1^m - X_1 \\
&= \Pi_1 + w\Phi_1^w + \Phi_1^s\gamma + K_1.
\end{aligned}
$$

When both traditional and modern technologies coexist, the wage is set to reservation wage at $\underline{w} = \gamma$, and hence $w\Phi_1^w + \Phi_1^s\gamma = wL_1$, where $L_1 \equiv 1 - \Phi_1^e$. Note that L_1 indicates the population proportion of non-entrepreneurs in sector 1. When the surplus labor exhausted and wage endogenously starts to grow exceeding γ, $\Phi_1^s = 0$, and again $w\Phi_1^w + \Phi_1^s\gamma = wL_1$. Therefore, total output in sector 1 can be written as

$$Y_1 = \Pi_1 + wL_1 + K_1. \tag{21}$$

Note that here the size of population in sector 1 is normalized to one. Equation (21) states simply that output per capita in sector 1 is the sum of factor payments (profit, wage income, and rental income) with the rental rate of capital being set to unity.

In sector 2, where the credit market is open, the profit π_{i2} of an agent i with setup cost x_i and wealth b_i who chooses to be a modern firm in sector 2 is given by:

$$\begin{aligned} \pi_{i2} &= \pi_2(x_i, w, r) \\ &= f(l_{i2}, k_{i2}) - wl_{i2} - rk_{i2} - x_i, \end{aligned}$$

where l_{i2} and k_{i2} denote *unconstrained* demands for labor and capital that depend only on market factor prices, i.e.,

$$\begin{aligned} l_{i2} &= l_2(w, r), \\ k_{i2} &= k_2(w, r). \end{aligned}$$

Note that entrepreneurial talent, i.e., the setup cost, influences only on the extensive margin of occupation choice, not the intensive margin of factor demands. This again implies that the size of modern firms are the same in the intermediated credit sector, although they may earn different levels of profit, depending on innate entrepreneurial talent.

Total output from modern firm Y_2^m in sector 2 can be similarly derived:

$$Y_2^m = \Pi_2 + wL_2^m + rK_2^m + X_2, \tag{22}$$

defining

$$\begin{aligned} \Pi_2 &= \int_0^{x_2^*(w,r)} \pi_2(x, w, r)dH(x), \\ L_2^m &= \int_0^{x_2^*(w,r)} l_2(w, r)dH(x), \\ K_2^m &= \int_0^{x_2^*(w,r)} k_2(w, r)dH(x), \\ X_2 &= \int_0^{x_2^*(w,r)} xdH(x), \end{aligned}$$

where $x_2^*(w, r)$ is given in (15).

The population fractions of three occupations in sector 2 are given:

$$\begin{aligned}\Phi_2^e &= H(x_2^*(w,r)) \text{ for entrepreneurs,}\\ \Phi_2^w &= L_2^m \text{ for wage laborers,}\\ \Phi_2^s &= 1-\Phi_2^e-\Phi_2^w \text{ for traditional subsisters.}\end{aligned}$$

Total output from traditional technology in sector 2 is

$$Y_2^s = \Phi_2^s\gamma. \tag{23}$$

Let K_2 denote the total wealth in sector 2. The wealth that is not used for modern production, $K_2 - K_2^m - X_2$, is invested now in bank with rate of return r, producing income

$$Y_2^b = r(K_2 - K_2^m - X_2). \tag{24}$$

Combining all these three sources of output in (22), (23), and (24), we get total output in sector 2, Y_2:

$$\begin{aligned}Y_2 &= Y_2^m + Y_2^s + Y_2^b\\ &= \Pi_2 + wL_2^m + rK_2^m + X_2 + \Phi_2^s\gamma + r(K_2 - K_2^m - X_2)\\ &= \Pi_2 + w\Phi_2^w + \Phi_2^s\gamma + rK_2 - (r-1)X_2.\end{aligned}$$

Again using the relationship between wage and subsistence income, Y_2 can be re-written as

$$Y_2 = \Pi_2 + wL_2 + rK_2 - (r-1)X_2, \tag{25}$$

where $L_2 = 1-\Phi_2^e$, which is the population share of non-entrepreneurs in sector 2. Note that here the population size in sector 2 is also normalized to one. Equation (25) states that output per capita in sector 2 is again the sum of factor payments (profit, wage income, and rental income) but subtracting the net rental income loss from capital of setup cost, as the opportunity cost of investing in setup capital is unity rather than the interest rate r.

3.1.2 Aggregation Between Sectors

Let p be the fraction of the intermediated sector in the entire economy. Then, economy-wide per capita output Y is a weighted sum of sectoral outputs Y_1 and Y_2:

$$\begin{aligned}Y &= (1-p)Y_1 + pY_2 &\quad (26)\\ &= wL + rK + \Pi - (r-1)U &\quad (27)\end{aligned}$$

where

$$\begin{aligned} L &= (1-p)L_1 + pL_2, && (28)\\ K &= (1-p)K_1 + pK_2, && (29)\\ \Pi &= (1-p)\Pi_1 + p\Pi_2, && (30)\\ U &= (1-p)K_1 + pX_2. && (31) \end{aligned}$$

The equation (27) is an accounting identity for national income per capita. It looks similar to standard income accounting identity except for two things. First, profit income Π is explicitly included. If the underlying technology were subject to constant returns to scale and the aggregate capital K captured all relevant capital factors, Π would be zero. Second, there is an adjustment term $-(r-1)U$, where U is a weighted sum of total capital in no-credit sector, K_1, and the capital used for setup cost in credit sector, X_2. These two kinds of capital do not earn positive net returns. In the income accounting equation (27), the aggregate capital of the whole economy K is priced by the gross interest rate r. The adjustment term corrects this mismeasurement of capital income, first due to the limited access to credit market, and second due to the existence of the presumed setup cost.

By differentiating both sides of (27) with respect to time and then dividing them by total output in base year, we get a growth accounting identity:

$$g_Y = s_L(g_L + g_w) + s_K(g_K + g_r) - s_U(g_U - g_r) + s_\Pi g_\Pi, \quad (32)$$

where

$$s_L = \frac{wL}{Y}, s_K = \frac{rK}{Y}, s_U = \frac{(r-1)U}{Y}, s_\Pi = \frac{\Pi}{Y}, \quad (33)$$

and g_V denotes the growth rate of variable V.[8]

In "standard" growth accounting *in per capita terms*, the Solow residual, SR, is measured by the difference between the output growth and the capital growth weighted by capital share such that:

$$SR \equiv g_Y - s_K g_K. \quad (34)$$

[8]The growth accounting formula in (32) is written as a growth rate of Divisia index in continuous time. In practice, with discrete-time data, we use the following decomposition formula between initial period s and final period t :

$$\begin{aligned} g_Y = & \frac{\overline{w}\Phi_s}{Y_s} g_\Phi + \frac{w_s\overline{\Phi}}{Y_s} g_w + \frac{\overline{r}K_s}{Y_s} g_K + \frac{r_s\overline{K}}{Y_s} g_r \\ & - \frac{(\overline{r}-1)U_s}{Y_s} g_U + \frac{(r_s-1)\overline{U}}{Y_s} g_r + \frac{\Pi_s}{Y_s} g_\Pi, \end{aligned}$$

where the upper bar denotes the average between periods s and t. Note that this formula is similar to the Tornqvist approximation (that uses average of factor shares between dates) to the Divisia index, but our formula for discrete data is an exact decomposition rather than an approximation. Hereafter, we apply this decomposition formula to all the following growth accounting.

When the input factors of capital and labor are *homogeneous* within each category, the standard Solow residual measures true TFP growth by definition. Surely the adjustment of quality variation is required for both capital and labor. This adjustment is for measuring the effective units of inputs. However, when there are different *kinds* of capital and labor in their nature, we need further adjustment for the composition of those kinds. For example, the same labor endowment is used for different kinds of activities across different occupations, which generates a heterogeneity for labor. The same wealth can be used between intermediated sector and non-intermediated sector and also between working capital for production and fixed setup cost, which generates another heterogeneity for capital. Thus, by accounting for these kinds of heterogeneity, the true TFP growth, $TFPG$, can be defined:

$$
\begin{aligned}
TFPG &\equiv g_Y - (s_K g_K - s_U g_U) - s_L g_L && (35) \\
&= SR - s_L g_L + s_U g_U. && (36)
\end{aligned}
$$

Note that the standard Solow residual diverges from the true TFP growth by two sources, $-s_L g_L$ and $s_U g_U$. Laborers and traditional subsisters earn less income than entrepreneurs doing different kinds of income-generation activities. Thus, aggregate productivity is enhanced as the population share of laborers and traditional subsisters, L, decreases. The term $-s_L g_L$ captures this effect of *occupational shift* on the TFP growth.

The existence of the setup cost and limited access to credit market generate the heterogeneity in capital via differential opportunity costs between the working capital and the capital for fixed setup cost, and also between the intermediated and non-intermediated sectors. The variable U measures the weighted sum of capital used for setup cost in the intermediated sector and the total capital used in the non-intermediated sector, the net returns of which are zero. The aggregate capital K includes two types of capital with different opportunity costs of saving (intermediated working capital versus non-intermediated and setup-cost capital) and the common rental rate r is used in calculating the capital share in standard growth accounting. Thus, the term $s_U g_U$ needs to be subtracted (recall $s_U = \frac{(r-1)U}{Y}$) from the contribution of aggregate capital accumulation $s_K g_K$ to output growth, which captures the effect of the *compositional change in heterogenous types of capital* on the TFP growth.

3.2 Decomposition of TFP Growth

In distinction from the standard TFP analysis, aggregate TFP growth does not remain as a residual but can be further decomposed into its underlying sources. The main idea is that growth accounting *by factor* and growth accounting *by sector* should each yield the same output growth. This will identify the sources of aggregate TFP growth in terms of the sectoral TFP growth and the various compositional changes on their extensive margins.

Using the sectoral decomposition of aggregate output in (26), we can get another version of growth accounting identity as follows:

$$g_Y = \{(1-p)s_{Y_1}g_{Y_1} + ps_{Y_2}g_{Y_2}\} + (s_{Y_2} - s_{Y_1})pg_p, \tag{37}$$

where

$$s_{Y_1} = \frac{Y_1}{Y},\ and\ s_{Y_2} = \frac{Y_2}{Y}.$$

The growth rate of aggregate output is equal to the weighted sum of growth rates of sectoral outputs, i.e., $(1-p)s_{Y_1}g_{Y_1} + ps_{Y_2}g_{Y_2}$ plus growth due to compositional change between sectors, i.e., $(s_{Y_2} - s_{Y_1})pg_p$. Note that the sectoral compositional change here corresponds to the change in the extent of intermediation, i.e., *financial deepening*, and the term $(s_{Y_2} - s_{Y_1})pg_p$ captures the direct effect of financial deepening on output growth.

Applying the growth accounting by factor to each sector, we have:

$$g_{Y_1} = TFPG_1 + (s_{L_1}g_{L_1} + s_{K_1}g_{K_1} - s_{U_1}g_{K_1}), \tag{38}$$

$$g_{Y_2} = TFPG_2 + (s_{L_2}g_{L_2} + s_{K_2}g_{K_2} - s_{U_2}g_{X_2}), \tag{39}$$

where

$$TFPG_1 \equiv SR_1 - s_{L_1}g_{L_1} + s_{U_1}g_{K_1}, \tag{40}$$

$$TFPG_2 \equiv SR_2 - s_{L_2}g_{L_2} + s_{U_2}g_{X_2}, \tag{41}$$

$$SR_1 \equiv g_{Y_1} - s_{K_1}g_{K_1}, \tag{42}$$

$$SR_2 \equiv g_{Y_2} - s_{K_2}g_{K_2}, \tag{43}$$

$$s_{L_1} = \frac{wL_1}{Y_1},\ s_{K_1} = \frac{rK_1}{Y_1},\ s_{U_1} = \frac{(r-1)K_1}{Y_1},\ s_{L_2} = \frac{wL_2}{Y_2},\ s_{K_2} = \frac{rK_2}{Y_2},\ and\ s_{U_2} = \frac{(r-1)X_2}{Y_2}.$$

Note that each sectoral Solow residual SR_j is not automatically zero although there is no within-sector technical change because we do not impose CRS on production technology. Other sources of the sectoral TFP growth, $TFPG_1$ and $TFPG_2$, include the within-sector compositional changes in heterogeneous labor ($-s_{L_1}g_{L_1}$ and $-s_{L_2}g_{L_2}$) and capital ($s_{U_1}g_{K_1}$ and $s_{U_2}g_{X_2}$).

Substituting equations (38) to (39) into (37), we get

$$\begin{aligned} g_Y &= (s_{Y_2} - s_{Y_1})pg_p + (1-p)s_{Y_1}TFPG_1 + ps_{Y_2}TFPG_2 \\ &\quad (1-p)s_{Y_1}(s_{L_1}g_{L_1} + s_{K_1}g_{K_1} - s_{U_1}g_{K_1}) + ps_{Y_2}(s_{L_2}g_{L_2} + s_{K_2}g_{K_2} - s_{U_2}g_{X_2}). \end{aligned} \tag{44}$$

Recalling the formula for the aggregate TFP growth in (35), we have

$$g_Y = TFPG + s_Lg_L + s_Kg_K - s_Ug_U. \tag{45}$$

The aggregate factor growth in (45) can be decomposed into sectoral factor growth:

$$g_L = \widetilde{s_{L_1}}(1-p)g_{L_1} + \widetilde{s_{L_2}}pg_{L_2} + (\widetilde{s_{L_2}} - \widetilde{s_{L_1}})pg_p, \tag{46}$$

$$g_K = \widetilde{s_{K_1}}(1-p)g_{K_1} + \widetilde{s_{K_2}}pg_{K_2} + (\widetilde{s_{K_2}} - \widetilde{s_{K_1}})pg_p, \tag{47}$$

$$g_U = \widetilde{s_{U_1}}(1-p)g_{K_1} + \widetilde{s_{U_2}}pg_{X_2} + (\widetilde{s_{U_2}} - \widetilde{s_{U_1}})pg_p, \tag{48}$$

where

$$\widetilde{s_{L_1}} = \frac{L_1}{L},\ \widetilde{s_{L_2}} = \frac{L_2}{L},\ \widetilde{s_{K_1}} = \frac{K_1}{K},\ \widetilde{s_{K_2}} = \frac{K_2}{K},\ \widetilde{s_{U_1}} = \frac{K_1}{U},\ and\ \widetilde{s_{U_2}} = \frac{X_2}{U}.$$

Substituting the equations (46) to (48) into the aggregate factor growth in (45), we get

$$\begin{aligned} g_Y \quad = \quad & TFPG + [s_{Y_2}(s_{L_2} + s_{K_2} - s_{U_2}) - s_{Y_1}(s_{L_1} + s_{K_1} - s_{U_1})]pg_p + \\ & (1-p)s_{Y_1}(s_{L_1}g_{L_1} + s_{K_1}g_{K_1} - s_{U_1}g_{K_1}) + ps_{Y_2}(s_{L_2}g_{L_2} + s_{K_2}g_{K_2} - s_{U_2}g_{X_2}). \end{aligned} \tag{49}$$

Equating the two versions of growth accounting identity (44) and (49), we get the following decomposition formula for TFP growth:

$$\begin{aligned} TFPG \quad = \quad & (1-p)s_{Y_1}TFPG_1 + ps_{Y_2}TFPG_2 \\ & +(s_{Y_2} - s_{Y_1})pg_p - [s_{Y_2}(s_{L_2} + s_{K_2} - s_{X_2}) - s_{Y_1}(s_{L_1} + s_{K_1})]pg_p. \end{aligned} \tag{50}$$

This suggests that aggregate TFP growth does not necessarily coincide with the weighted sum of sectoral TFP growth: the difference between them represents the effect of financial deepening.

Substituting (40) and (41) into (50), we can re-arrange the above decomposition formula as follows:

$$TFPG = TFPG\_SSR + TFPG\_OCC + TFPG\_ACH + TFPG\_FIN \tag{51}$$

where

$$TFPG\_SSR \quad \equiv \quad (1-p)s_{Y_1}SR_1 + ps_{Y_2}SR_2, \tag{52}$$

$$TFPG\_OCC \quad \equiv \quad -(1-p)s_{Y_1}s_{L_1}g_{L_1} - ps_{Y_2}s_{L_2}g_{L_2}, \tag{53}$$

$$TFPG\_ACH \quad \equiv \quad (1-p)s_{Y_1}s_{U_1}g_{K_1} + ps_{Y_2}s_{U_2}g_{X_2}, \tag{54}$$

$$TFPG\_FIN \quad \equiv \quad (s_{Y_2} - s_{Y_1})pg_p - [s_{Y_2}(s_{L_2} + s_{K_2} - s_{U_2}) - s_{Y_1}(s_{L_1} + s_{K_1} - s_{U_1})]pg_p. \tag{55}$$

This shows that the aggregate TFP growth is decomposed into four underlying sources: (i) the weighted sum of sectoral Solow residuals ($TFPG\_SSR$), (ii) the effect of compositional change in occupation ($TFPG\_OCC$),

(iii) the effect of adjusting capital heterogeneity ($TFPG\_ACH$), and (iv) the effect of financial deepening ($TFPG\_FIN$).

The effect of financial deepening can be further decomposed into two components in (55): the effect due to the output gap between sectors, measured by $(s_{Y_2} - s_{Y_1})pg_p$, and the effect due to the difference in factor shares between sectors, measured by $-[s_{Y_2}(s_{L_2} + s_{K_2} - s_{U_2}) - s_{Y_1}(s_{L_1} + s_{K_1} - s_{U_1})]pg_p$. Combining these two, the effect of financial deepening on the TFP growth can be re-written:

$$
\begin{aligned}
TFPG\_FIN &= [s_{Y_2}(1 - s_{L_2} - s_{K_2} + s_{U_2}) - s_{Y_1}(1 - s_{L_1} - s_{K_1} + s_{U_1})]pg_p && (56) \\
&= \left(s_{Y_2}\frac{\Pi_2}{Y_2} - s_{Y_1}\frac{\Pi_1}{Y_1} \right) pg_p, && (57)
\end{aligned}
$$

showing that the financial deepening can contributes to the TFP growth if and only if the intermediated sector is more *profitable* than the non-intermediated sector. As long as there exists an output gap between two sectors such that $Y_2 > Y_1$, financial deepening contributes to aggregate *output* growth. However, the effect of financial deepening on *productivity growth* comes through the *profitability* gap between sectors, not the output gap. A priori assumption of CRS leads to identical profits of all entrepreneurs at zero in both sectors and precludes this source of productivity growth from financial deepening.

4 Data

4.1 Data Sources

Thailand experienced fast economic growth as well as enormous structural changes for the two decades between 1976 and 1996. Our growth accounting method requires a use of both macro and micro data. Macro data are obtained from various sources from the Thai government institutions. The series for Gross Domestic Product (GDP) and capital stock are obtained from National Economic and Social Development Board (NESDB), both denominated in 1988 Thai baht. The labor employment series are from Labor Force Survey (LFS) collected by National Statistical Office (NSO). Due to the large share of agricultural sector in Thailand, the contribution of land expansion may not be negligible. Thus, we measure the land size by the total area of cultivated land, obtained from the Ministry of Agriculture and Cooperatives (MOAC). The factor share data are obtained from the Thailand Development Research Institute (TDRI), documented by Tinakorn and Sussangkarn (1994, 1998). We use the labor share data in Tinakorn and Sussangkarn (1998), who use the imputed wage from Social Accounting Matrix (SAM) with base year 1995, rather than the wage from the national income accounts.[9] The quality of labor is adjusted by taking wage differentials across different population groups into account (by age, gender, and education), again following Tinakorn and Sussangkarn (1998). These data are needed in

[9]See the discussion of Tinakorn and Sussangkarn (1994, 1998) on the problem of using wage income from national income accounts in Thailand.

calculating the annual series of the Thai TFP growth for the two decades according to the standard macro growth accounting method.

The micro data on the wealth distribution, occupation choices, and financial deepening are taken from Jeong (2000), using the nationally representative household surveys, the Thai Socio-Economic Survey (SES), collected by NSO. In particular, to simulate the model economy, we need the initial wealth distribution and the path of financial deepening that is to be exogenously embedded into the model. The initial wealth distribution is estimated from the 1976 SES household assets data using the principal-component analysis.[10] We use the dichotomous occupation categories as the theory suggests. The self-employed and employers in the non-agricultural sectors are categorized as entrepreneurs. Wageworkers and farmers are categorized into wage laborers and traditional subsisters, respectively. The extent of financial deepening is measured by the rate of participation in formal financial institutions in the Thai population. Using the SES data, we count the number of households who actually use in the previous month any of the financial institutions: commercial banks, savings banks, Bank for Agriculture & Agricultural Cooperative (BAAC), government housing banks, financial companies, and credit financiers, and consider them as participants in the intermediated sector. The rest are non-participants.

4.2 Standard Growth Accounting in Thailand

Figures 1.1 and 1.2 display the growth rates and payment shares of the three factors, respectively. The growth rate of capital is more or less steady (at 7.8 percent on average), with a sudden acceleration between 1986 and 1990. The growth rate of labor is smaller (at 2.2 percent on average) but fluctuates more than capital. The growth rate of land is even smaller (at 0.8 percent on average) but moves most widely. However, land share is small (5 percent on average) and is steadily declining to 2.8 percent by 1996. Labor and capital shares are fairly stable until 1990, but the labor share shows an increasing trend while the capital share shows a decreasing trend after 1990. The average factor shares are 40 percent for labor and 55 percent for capital.

Figure 1.3 decomposes the total input growth into the growth rates of three factors, each being weighted by its own factor share, using the Divisia index method. The contribution of land expansion is virtually negligible. Both the growth pattern and the magnitude of input growth are mainly determined by capital accumulation. Though not negligible, the labor growth adds a small contribution.

Thai output, measured by real GDP in 1988 baht value, grows at 7.5 percent on average each year with a clear acceleration in 1986, peaking in 1988, and then a gradual decline until 1996. The standard growth accounting, *using only these macro data*, calculates the TFP growth as the difference between output growth and input growth, where the input growth is measured from the sum of growth rates of factors (capital, labor,

[10]See Jeong (2000) and Jeong and Townsend (2003) for the details of the estimation procedure.

and land) weighted by their factor shares. Equation (35) provides a formula for this in per capita terms. Figure 1.4 decomposes the Thai output growth into the input growth and the TFP growth according to the standard growth accounting. The input growth contributes to 5.3 percent out of the total 7.5 percent of output growth. Its contribution steadily increases until 1991 but begins to decline thereafter. The TFP grows at 2.2 percent on average but is subject to substantial fluctuations, closely tracking the fluctuation of output growth. In particular, the TFP growth surges in 1986, peaks in 1988 like the output growth, and then declines to near zero after 1991.

5 Simulation

We now bring both the macro and micro data to the model to select model's parameters and initial wealth distribution (the fundamental inputs of the model). The parameters are chosen to fit the aggregate Thai output growth rate and factor shares from the macro data and the initial wealth distribution is estimated from the micro data, the Thai SES. We then simulate the model. The simulation will help us to understand the underlying mechanisms and sources of the TFP growth. Finally, we bring the model back to the data to further decompose the aggregate TFP growth.

5.1 Calibration

We calibrate the parameters of the model. The preference parameter ϖ, propensity to save, is calibrated at 0.3 to match the *average* savings rate in the national income accounts of Thailand during the two decades between 1976 and 1996. The subsistence return parameter γ is calibrated at 0.019 to match the 1976 annual wage payment at a scale of 10^{-7} that converts Thai baht unit into the model income unit. Here, we suppose the 1976 Thai wage to be close to the reservation wage, $\underline{w} = \gamma$ in the model. In fact, the occupational shift from farmers to wage earners was quite fast in the Thai economy during the first decade of 1976-1986, but the Thai wage grew only slowly for the period, relative to the second decade of 1986-1996. Thus the approximation of γ by the 1976 wage seems reasonable.

To be consistent, the initial wealth distribution in the Thai data is put into the model using the same scale that converts Thai baht unit to the model income unit. Thus, given the bounded support and additive nature of the setup cost x and the borrowing constraint in (4), the choice of scale is important for the growth dynamics of the model, not only through the value of γ but also through the scale of initial wealth distribution. For instance, the higher the scale is, i.e., the wealthier the model economy becomes, the higher is the fraction of entrepreneurs, but too much wealth may induce the agents consume their wealth rather than save it and the economy suffers from negative growth initially. The higher is the scale, the greater is this initial negative growth, although this relationship is not monotone. Eventually the economy starts to grow, but overall growth for the entire sampling period can be negative when the initial negative growth is too large. So we restrict the range of scale parameter and select a scale parameter that generates the patterns of the observed aggregate growth in Thailand.[11]

Conditional on ϖ, γ, and scale parameter, the technology parameters α, β, ξ, ρ, and σ are calibrated to match the key aggregate objects in growth accounting exercise, i.e., the paths of GDP growth rate and labor share in Thailand for the period of 1976-1996, using an explicit root-mean-squared-error criterion (the two paths being equally weighted). Thus the model economy is aligned to mimic the patterns of aggregate growth of the actual Thai economy. (Note again that this calibration of technology parameters is done along with the search of the scale parameter.) Table 1 summarizes the selected parameters.

Table 1. Model Parameters

ϖ	γ	α	β	ξ	ρ	σ
0.30	0.019	1.111	0.001	0.100	0.0063	0.000

5.2 Aggregate Dynamics

The simulated economy tracks output growth and the labor share of Thailand well, as is shown in Figures 2.1 and 2.2. The simulated annual growth rate is a little lower than the actual Thai data (varying from 4 to 14 percent), which may indicate that the model misses some of the engines of growth in Thailand. However, the dynamic patterns of the Thai growth, the slow-down in early 1980's, the surge after 1986, and the continual decline thereafter, are very well captured by the model economy. The simulated labor share is a little lower than the Thai data (varying from 35 to 45 percent), but again the model captures the dynamic patterns like the upturn of the labor share after 1990 in the data. This is mainly due to the wage growth rather than the change in employment, both in the model and the data.

The population fraction of the credit sector, which is estimated from the SES data, represents the level of financial deepening. This is displayed in Figure 2.3, showing a non-linear expansion of the financial sector, and exogenously embedded into the model. The participation rate in the financial sector increases gradually from 6 to 10 percent for the first decade, and then accelerates after 1986 from 10 to 27 percent. The fraction of entrepreneurs in the model is lower than the data and the gap is large, as shown in figure 2.4.[12] The Thai population fraction of entrepreneurs stays constant around 15 percent, and only after 1990, does it begin to

[11] In Jeong and Townsend (2003), the scale parameter of the same model was chosen under the same kind of restriction of excluding overall negative growth, but to maximize the likelihood of the occupation choice in the micro data, i.e., the SES. The chosen scale there was $0.6 * 10^{-7}$. We do perform a sensitivity analysis at this scale in the following subsection.

[12] Here, the category of entrepreneurs in the data is a bit broad, including both employer and self-employed in non-agriculture. When we include employers only, the gap in the fraction of entrepreneurs between the model and the data becomes quite small. However, with a view to identifying the occupation of entrepreneurs by their activity of generating profits, broad category of entrepreneurs seems more appropriate. Fortunately, the dynamic pattern, the gradual increase in the fraction, is invariant to both broad and narrow categorization of entrepreneurs.

rise, reaching 19 percent by 1996. The simulated fraction of entrepreneurs also gradually increases from 1.5 to 8.4 percent, with acceleration in 1986 when the rate of financial deepening accelerates.

The most remarkable performance of the model is its prediction for TFP growth. The Thai TFP growth series are calculated following the *standard* growth accounting practices, using the aforementioned various sources of data, as the difference between the growth rate of real GDP and the sum of growth rates of three factors (capital, land, and quality-adjusted labor) weighted by the output shares of the factors. The average Thai TFP growth rate for the two decades 1976-1996 is 2.4 percent, fluctuating from -1.6 percent in 1980 to 7.8 percent in 1988. The Thai TFP growth is compared with the simulated TFP growth, calculated from (35), in Figure 2.5, showing that the simulated TFP growth tracks the actual Thai TFP growth remarkably well, both in terms of the co-movement and the orders of magnitude.

Figures 3.1 shows that the interest rate starts at very high level and continuously declines (with the exception in 1986 when the financial expansion starts to accelerate). This is a typical feature of diminishing returns to capital accumulation. Figure 3.2 shows that wage stays constant at the reservation level of γ until 1990 and then continuously grows. The movements of profit differ between the two sectors as Figure 3.3 shows. In the non-intermediated sector, profit is more or less constant over time even when the wage grows. In the credit sector, however, profit sharply increases during the first three periods, becomes stable, and then declines when the wage grows. Overall, average profit gradually increases until 1990 and then becomes constant. The profitability gap, measured by $\left(s_{Y_2}\frac{\Pi_2}{Y_2} - s_{Y_1}\frac{\Pi_1}{Y_1}\right)$ as in (57), determines the size of the effect of financial deepening on the aggregate TFP growth. Figure 3.4 shows that it first increases sharply for the initial three periods, stays constant until 1986, and then continuously declines after the non-linear financial sector expansion.

5.3 Decomposition of TFP Growth

The period of upturn of output growth rate coincides with the accelerated expansion of participation in the financial sector in Thailand. Thus, the output growth in Thailand seems to be related to that financial expansion. In an accounting sense, when the credit sector produces more output, i.e., the agents in the credit sector earns more income than the non-credit sector, the expansion of the credit sector contributes to growth in aggregate output. The decomposition analysis for the SES in Jeong (2000) suggests that, combined with changes in occupational composition, financial expansion accounts for 36% of the Thai income growth for the two decades 1976-1996. Financial expansion alone accounts 20% of the overall growth. Furthermore, for the acceleration period of the expansion of financial sector, i.e., 1986-1992, the financial expansion contributes to income growth at 27%. That is, the upturn of the output growth is apparently quite related to the accelerated financial expansion. The patterns of the TFP growth, the decline in early 1980's and then the surge when the expansion of financial sector accelerates, resembles those of output growth in both the model and the data. These observations give us the clue: the effects of financial expansion on output growth are through TFP growth. Moreover, we now identify the sources of the simulated TFP growth using the decomposition formula (51) and explicitly check if this is indeed so.

Figure 4.1 displays from the model the four components of the aggregate TFP growth, $TFPG\_SSR$, $TFPG\_OCC$, $TFPG\_ACH$, and $TFPG\_FIN$, calculated from the equations (52) to (55), respectively. The sum of the sectoral Solow residuals, $TFPG\_SSR$, turns out to be negligible. So are the occupational shift effects, $TFPG\_OCC$. This negligible size of $TFPG\_OCC$ may look puzzling, recalling the gradual but significant occupational shift from laborers and traditional subsisters to entrepreneurs in the model, as shown in Figure 2.4. Using the equation (46), the total effect of occupational shift, $-s_L g_L$, is given by:

$$\begin{aligned} -s_L g_L &= -s_L\{\widetilde{s_{L_1}}(1-p)g_{L_1} + \widetilde{s_{L_2}}pg_{L_2} + (\widetilde{s_{L_2}} - \widetilde{s_{L_1}})pg_p\} \\ &= -(1-p)s_{Y_1}s_{L_1}g_{L_1} - ps_{Y_2}s_{L_2}g_{L_2} - (s_{Y_2}s_{L_2} - s_{Y_1}s_{L_1})pg_p \\ &= TFPG\_OCC - (s_{Y_2}s_{L_2} - s_{Y_1}s_{L_1})pg_p. \end{aligned}$$

Here, the total effect of occupational shift includes $TFPG\_OCC$, the weighted sum of effects from within-sector occupational shifts, and the effect of occupational shift due to the expansion of the credit sector, i.e., $-(s_{Y_2}s_{L_2} - s_{Y_1}s_{L_1})pg_p$. The average fraction of entrepreneurs in the credit sector in the model is 30 percent while it is only 1 percent in the non-credit sector. Due to this gap, simply expanding the credit sector can increase the aggregate fraction of entrepreneurs without changing $TFPG\_OCC$ when there are no within-sector occupational shifts. The direct source of the latter effect is in fact the financial expansion, and we attribute this effect to $TFPG\_FIN$.

The interest rate determines the differential rates of returns between heterogeneous types of capital and the size of $TFPG\_ACH$, i.e., the effect of changes in the composition of heterogeneous types of capital depends on the movement of market interest rate. This effect turns out to be significant only for the first three periods when the interest rate is very high and quickly declining. (See Figure 3.1.)

Except for those three periods, the effect of financial deepening, $TFPG\_FIN$, almost entirely explains the simulated TFP growth. Figure 4.2 decomposes $TFPG\_FIN$ into the output-gap effect $(s_{Y_2} - s_{Y_1})pg_p$ and the input-differential effect $-[s_{Y_2}(s_{L_2} + s_{K_2} - s_{U_2}) - s_{Y_1}(s_{L_1} + s_{K_1} - s_{U_1})]pg_p$ as in equation (55). This shows that main reason financial deepening contributes to the TFP growth is the output-gap rather than the difference in factor shares between the intermediated sector and the non-intermediated sector.

Figures 4.3 and 4.4 decompose the within-sector TFP growth in each sector, $TFPG_1$ and $TFPG_2$, using (40) and (41), respectively. They show first that the within-sector occupational shift effects ($-s_{L_1}g_{L_1}$ for non-credit sector and $-s_{L_2}g_{L_2}$ for credit sector) are tiny if not zero in both sectors. The effects of compositional change in heterogeneous capital for the initial periods come mainly from the credit sector but are very small after the initial three periods. The non-credit-sector Solow residual SR_1, defined in (42), surges in 1990 precisely when the wage starts to grow and this is the main determinant of the non-credit sector TFP growth $TFPG_1$, as shown in Figure 4.3. In the credit sector, however, the Solow residual SR_2, defined in (43), together with the $TFPG_2$ turn negative and counter-move with SR_1 and $TFPG_1$ after the wage starts to grow.

The asymmetric effects of wage growth on the sectoral Solow residuals can be better understood from the *dual* expression of the sectoral Solow residual, SR_j^d, which is a weighted sum of growth in factor prices including profit:

$$SR_j^d = s_{L_j} g_w + s_{K_j} g_r + s_{\Pi_j} g_{\Pi_j}, \tag{58}$$

for each sector $j = 1$, and 2. Hsieh (2002) provides a clear discussion on how to use the factor price data in accounting for the East Asian economic growth in this dual framework, but he ignores profits component in his application. Obviously, wage growth has a direct and positive contribution to the Solow residual, but it may decrease profit and reduce the Solow residual. In particular, wage growth decreases profit in the credit sector for sure because all entrepreneurs earn optimal profit, which is a decreasing function of wage as in (5.3). Thus, the overall effect of wage growth on Solow residual depends on the relative share of wage income to profit income, which is much larger in the non-credit sector than the credit sector. The rental shares are about the same between the two sectors, 0.29 in the non-intermediated sector, and 0.24 in the intermediated sector, and the effects of change in interest rate on the sectoral TFP growth are similar between the two sectors. Thus, the asymmetric response of the sectoral TFP growth is related to wage growth, not to the change in interest rate. On average, $s_{L_1} = 0.57$ and $s_{\Pi_1} = 0.14$ in the non-credit sector while $s_{L_2} = 0.07$ and $s_{\Pi_2} = 0.69$ in the credit sector. Thus, the net contribution of wage growth on the Solow residual may well be larger in the non-credit sector than in the credit sector. It is in fact even negative in the credit sector. It is interesting to notice the possibility that the same wage growth boosts the TFP growth in one sector but hurts the other sector. In the non-intermediated sector, where most people live on wage or traditional self-employed income, wage growth plays a positive role in increasing the productivity growth. However, in the credit sector, where modern business is active, the direct positive contribution of the wage growth may be more than offset by the indirect negative effect on the TFP growth via profit reduction.

Substituting the dual version of the sectoral Solow residuals SR_j^d for $j = 1$ and 2 as in (58) into $TFPG\_SSR$ in (52), we get

$$\begin{aligned} TFPG\_SSR &= (1-p)s_{Y_1}(s_{L_1}g_w + s_{K_1}g_r + s_{\Pi_1}g_{\Pi_1}) + ps_{Y_2}(s_{L_2}g_w + s_{K_2}g_r + s_{\Pi_2}g_{\Pi_2}) \\ &= s_L g_w + s_K g_r + [(1-p)s_{Y_1}s_{\Pi_1}g_{\Pi_1} + ps_{Y_2}s_{\Pi_2}g_{\Pi_2}], \end{aligned} \tag{59}$$

which shows that the overall effect depends on economy-wide effects of growth in wage and rental rates and the differential profit growth between the sectors. The overall effect of $TFPG\_SSR$ was already shown to be nil in Figure 4.1 although again within-sector Solow residuals respond to wage growth substantially, as is evident in Figures 4.3 and 4.4, after 1990.

5.4 Sensitivity Analysis

Here, we check the robustness of our simulation results, focusing on the output growth, TFP growth, and the decomposition of TFP growth. We perturb the parameter values around those of the above benchmark. There are restrictions on the parameter space implied by the structure of the model. They suggest possible ranges of variation of parameters in this sensitivity analysis. The critical setup cost function z in (11) is an increasing concave function in wealth, which implies an order among critical values that characterize this function:

$$0 \leq \widehat{b}(w) \leq x^*(w) \leq b^*(w),$$

which in turn implies that

$$C_0(w) \geq w, \tag{60}$$

$$C_1(w) \geq 0, \tag{61}$$

$$C_2 \leq 0. \tag{62}$$

Then, combining equations (8) to (10) with these inequality constraints (60) to (62), the parameters should satisfy that

$$\rho > 0, \tag{63}$$

$$\max\left\{-\frac{\rho(\alpha-1)}{\xi-w}, -\sqrt{\beta\rho}\right\} \leq \sigma \leq \sqrt{\beta\rho}, \tag{64}$$

for any positive wage w. This suggests that appropriate ranges of parameters are determined interdependently among each other. We perform sensitivity analysis within this parameter space.

Given technology parameters α, β, ξ, ρ, and wage w, the legitimate range of σ is bounded both from below and from above. Furthermore, excluding negative complementarity between labor and capital, the lower bound of σ is zero. Thus, in the neighborhood of the calibrated parameters of the benchmark economy, the possible range of σ is indeed tightly bounded by $[0, 0.0025]$. Varying σ over this range makes for virtually no changes. Figure A.1 shows the growth dynamics and the decomposition at the maximum $\sigma = 0.0025$.

With σ at zero, the non-constant coefficients of the profit function C_1 and C_2 are effectively determined by α and β, i.e., $C_1 = \alpha - 1$, and $C_2 = -\frac{2}{\beta}$, independent from the wage. Thus changes in α and β may affect the shape of the profit function, and subsequently the growth dynamics, but not in relation to the wage. With σ at zero, changes in α and β may affect x^* and b^*, but again not in relation to the evolution of the wage, i.e., these changes do not shift the occupation map over time.[13] Note that the main driving force behind the growth dynamics of the model is the interaction between occupation choice and capital accumulation. Therefore, the growth dynamics remain robust to the perturbation of α and β. Varying α over $[1, 1.3]$ and β over $[0.0001, 0.1]$ indeed makes for virtually no changes. Figure A.2 shows the case with $\alpha = 1.3$.

In contrast, the other technology parameters ξ and ρ can directly affect both growth dynamics and occupation choice via $C_0(w)$ in relation to wage, although σ is near zero. An increase in ξ implies an increase in the intercept term $C_0(w)$ of the profit function. It also implies an increase in marginal productivity of labor by constant term ($MPL = \xi - \rho l$ with σ at zero). This makes the modern business more profitable and draws more savings into the modern technology, which is more productive than the traditional one. Thus output and productivity growth becomes faster. Figure A.3, increasing ξ by 10 percent to 0.11, confirms this. Comparing the decomposition results with those of the benchmark economy, we find that the dynamic patterns of all underlying sources of the TFP growth remain the same although the magnitude of fluctuations is larger.

An increase in ρ plays a similar role to a decrease in ξ, i.e., decrease in profitability of modern business. Figure A.4 displays that increasing ρ from 0.0063 to 0.0080 reduces output growth as well as the TFP growth. Here, again the dynamic patterns of the underlying sources of the TFP growth are the same as the benchmark case but the magnitudes of fluctuation become smaller.

The value of ω was calibrated at 0.30 to match the aggregate savings ratio. The Thai SES suggests a lower estimate of average savings rate at 0.25 with standard deviation 0.02. A decrease in ω induces less saving, which makes capital accumulation slower and occupational transition of the constrained households more difficult. Figure A.5 shows that lowering ω to 0.25 reduces output growth and TFP growth but only slightly. The decomposition results are again robust.

The choice of γ affects two things. First, it determines the relative productivity of the traditional technology to the modern technology and hence the income gap across occupation groups, and second, the wealth scale of the model economy. As γ decreases, the traditional technology becomes less productive and thus widens the occupational income gap. This increases the *incentives* for the occupational shift into modern business, which tends to promote growth. At the same time, a decrease in γ makes the economy poorer and increases the degree of constraints for the occupational shift into modern business, which makes growth deteriorate. The overall effect cannot be determined *a priori*. However, the patterns of both growth dynamics and the decomposition results remain robust to the perturbation of γ over $[0.012, 0.025]$ although magnitude of fluctuations differs. Figure A.6 displays the case of reducing γ to 0.012. Both the output and the TFP growth are accentuated during the period of acceleration of financial expansion, but again the occupational shift effects are virtually

[13] Varying σ away from zero, a change in α could affect income and occupation choice in relation to wage via $C_1(w)$. However, the range of σ $[0, 0.0025]$ turns out to be not wide enough to generate any significant changes.

zero.[14]

In sum, the simulated dynamics of output and TFP growth and the sources of TFP growth turn out to be robust to the perturbation of the model parameters. In particular, changes in α, β, and σ make virtually no difference. The parameters ξ, ρ, ω, and γ seem more important in determining the dynamics of output and TFP growth. However, the orders of magnitude of change from varying these parameters in the neighborhood of the benchmark economy are small. In particular, the importance of financial deepening on the TFP growth is robust to every perturbation.

6 Sources of Actual Thai TFP Growth

6.1 Decomposition of Actual TFP Growth

Let's bring the model back to the actual data. If we had all pieces of data in the decomposition formulae (51) to (55), we might apply the same decomposition method to the actual Thai economy, precisely as we did to the simulated Thai economy above. The fundamental difficulty is that the economy is partitioned via the access to credit and it is impossible to differentiate key variables such as factor shares and capital use between credit sector and non-credit sector from the macro data. Fortunately, the use of micro data allows us to go inside the residual TFP growth.

We partition the households into two groups, non-participant group (sector 1) and participants group (sector 2), from the financial asset transaction records of the SES, as was explained in Section 4. Then, some key pieces of data for the components of TFP growth in (52) to (55) can be obtained from the SES. The within-sector occupational shift terms, g_{L_1} and g_{L_2} in (53), are measured by the growth rates of population shares of entrepreneurs within each group, from the household characteristics data in the SES. The sector share data $(1-p)s_{Y_1}s_{L_1}$ and $ps_{Y_2}s_{L_2}$, i.e., the coefficients of g_{L_1} and g_{L_2} in (53), are measured by the income shares of the two groups, from the household income data in the SES. Thus, we compute the actual $TFPG\_OCC$ in (53) for Thailand.

Unfortunately, even partitioning the population by the access to credit, the data on capital stocks and capital shares at sectoral level such as s_{K_1}, s_{U_1}, s_{K_2}, s_{U_2}, g_{K_1}, g_{K_2}, and g_{X_2} are not available from the household survey, and the components of $TFPG\_SSR$ and $TFPG\_ACH$ cannot be constructed separately. Neither is the complete calculation of the $TFPG\_FIN$ component possible due to the lack of information. However, we can recover part of it. The level and change of participation rate, p and g_p, are constructed from the population share of the participants in the financial sector. The coefficient $(s_{Y_2} - s_{Y_1})$ on pg_p is measured by the gap in relative income between two sectors, which is available again from the household income record in the SES. Thus, the

[14] The γ value at 0.012 is chosen in the previous study by Jeong and Townsend (2003), which maximizes the likelihood of occupation choice of the Thai households from structural estimation.

output gap effect of $TFPG\_FIN$, which was the dominant component of $TFPG\_FIN$ in the simulation, can be calculated.

Approximating the $TFPG\_FIN$ by $(s_{Y_2} - s_{Y_1})pg_p$, and precisely computing the $TFPG\_OCC$ from the SES, Figure 5.1 decomposes the actual Thai TFP growth, obtained from the macro growth accounting in Section 4, into the underlying sources. Here, again, the occupational shift effect $TFPG\_OCC$ turns out to be negligible and the financial deepening contributes to the actual TFP growth as in the simulated TFP growth. The "Remainder" in includes both $TFPG\_SSR$ and $TFPG\_ACH$. This component of the TFP growth fluctuates the most widely tracing the total TFP growth.

The size and movement of the two components of $TFPG\_OCC$ and $TFPG\_FIN$ can be directly confirmed as above and also compared with the model simulation. Figure 5.2 compares the $TFPG\_OCC$ components between the model and the actual Thai data, showing that both are near zero within the range of -0.2 to 0.5 percent although increasing from zero to 0.5 percent after 1990 in the actual data. Figure 5.3 shows a remarkable resemblance of the financial deepening effects $TFPG\_FIN$ between the model and the data. The simulated $TFPG\_FIN$ is a bloated version of the actual one but the movements over time virtually coincide.

The "Remainder" components are compared between the model and the data in Figure 5.4, showing that the simulated remainder term tracks the actual one quite closely until 1985 and then counter-moves until 1994. Given the data limitation, the actual remainder term cannot be further decomposed. However, the decomposition of the simulated TFP growth helps us to infer the possible sources of this remainder term in the data. Figure 4.1 suggests the initially high but declining TFP growth is possibly due to $TFPG\_ACH$, the effect of compositional change in heterogeneous types of capital during the initial periods 1976-1980. Neither from national income data nor from typical household surveys is direct confirmation of this effect possible, because of the difficulty of observing differential rates of returns as well as the structure of capital between intermediated and non-intermediated sectors. A synthesis between two types of micro data, i.e., firm surveys and household surveys seems needed to confirm this conjecture.

We learned from the simulation (Figures 4.3 and 4.4) that the sectoral Solow residual, $TFPG\_SSR$, may respond to wage growth, particularly when the wage jumps up and that the overall effect of wage growth on the Solow residual, $TFPG\_SSR$, depends on the relative income shares among wage, rental, and profit. In particular, the response of profit to wage growth may differ across sectors, which may in turn generate an asymmetric response of the Solow residuals across sectors. Figure 6 shows that the Thai wage started to grow in 1986, earlier than in the simulation. Thus, though not entirely, part of the remainder TFP growth in Thailand for the second decade 1986-1996 is likely to be related to the wage movement in Thailand. The dual expression of $TFPG\_SSR$ in (59) suggests that there are no *a priori* directions of this effect on the Solow residual because there are no uniform responses of profits between the non-intermediated and intermediated sectors and because relative factor income shares are varying over time. Thus, its effect can be positive or negative. The model suggests that wage growth can substantially reduce profits particularly in the credit sector. This is because every entrepreneur is unconstrained in hiring capital and labor, and obtains the optimal profit function, which is a decreasing function in wage. Therefore, the more the wage grows, the smaller the profit in the credit sector becomes, which makes the sectoral Solow residual more negative. This can explain why the remainder TFP growth in Thailand turns from positive to negative during the second decade, as the wage growth continues. However, regarding the surge of the remainder TFP growth during 1986-1988, the model is silent and this remains a puzzle.

In sum, the above decomposition from a synthetic use of macro and micro data under the specific growth model delivers several lessons. First, the financial deepening substantially contributes to the actual Thai TFP growth while the occupational shift from laborers and farmers to non-farm entrepreneurs does only slightly. By filtering out these compositional effects from the standard TFP growth (2.2 percent on average), the remainder TFP growth becomes 1 percent during the entire two-decade period 1976-1996 and 0.4 percent during the second decade 1986-1996 on average. That is, "our measure of ignorance" is reduced to more than half by identifying the two kinds of compositional effects from the micro data. Second, the Solow residual, even after filtering the compositional effects out, can be non-zero. The theory (without incorporating exogenous technical changes) helps us to interpret, though not entirely, part of the remainder term of the Thai TFP growth. The initially high but declining TFP growth during 1976-1980 may come from the compositional change in heterogeneous types of capital. The turning of positive TFP growth to negative for 1988-1996 may come from the sectoral Solow residual in relation to the wage growth started from 1986. However, the surge of the remainder TFP growth during 1986-1988 remains a puzzle.

6.2 Factor Accumulation and TFP Growth

Combining the standard growth accounting results in Section 4.2 with the above TFP growth decomposition results according to equations (51) to (52), we can identify the sources of the Thai growth and the patterns of their movements. Figure 7 displays the four major sources of the Thai growth, capital accumulation, increase in effective labor, TFP growth from financial deepening, and the remainder TFP growth, dropping the two minor sources of growth, i.e., the land expansion and the occupational shift from laborers and farmers to non-farm entrepreneurs.

We find that, with a few exceptional periods, capital accumulation contributes the most to the Thai growth, and it was quite stable during the first decade. The contribution of labor growth fluctuates more than that of capital accumulation. During the second decade when the financial sector expanded, all three components, capital accumulation, the financial-deepening TFP growth, and the remainder TFP growth surged, which "explains" the growth-peak period of Thailand. The wage also started to grow with the financial expansion. Thus, the expansion of financial sector not only directly increased the productivity of the Thai economy but also seemed to foster the capital accumulation. The contributions of these three components declined with different peaks and speeds. The contributions of capital accumulation and the financial-deepening TFP growth declined gradually after 1991. The remainder TFP growth peaked earlier in 1988 and then quickly declined to negative. Another interesting observation is that after 1991, all components except the remainder TFP growth declined and the remainder TFP growth was negative, presaging perhaps the upcoming financial crisis in 1997.

7 Conclusion

The existing literature of TFP usually measures the size of TFP but rarely identifies its sources directly. The sources of the TFP growth typically remain unknown inside the *residual*. We attempted to find what is inside of the residual by integrating the model with the data and by synthesizing the micro data with the macro data. Specifying a growth model that articulates the micro underpinnings, we brought the actual macro data to the model to choose the parameter values that best mimic the actual aggregate output growth patterns. At those parameter values, initial wealth distribution and the participation rates in the financial sector were obtained from the micro data and were exogenously embedded into the model to simulate the economy. The simulated TFP growth was decomposed into four components; occupational-shifts effect, financial-deepening effect, capital-heterogeneity effect, and the sum of sectoral Solow residuals. Then, we brought the model back to the data and showed how to decompose the TFP growth of the actual economy using the micro data.

The model in this paper emphasizes two important extensive margins that create the productivity differential across sectors and activities in the economy. First, the rates of return to the same time endowment are different across occupations. Second, the rates of return to the capital and hence the profitability of modern firms also differ between the credit sector and the non-credit sector. Expansion of the credit sector improves the aggregate efficiency not only directly via the second type of profitability margin but also indirectly via the first type of occupational margin. Thus, financial deepening can be an important source of productivity growth. The occupational shifts within each sector can also be a separate source of productivity growth. These sources of productivity growth may well be particularly important for the economies in transition and they can be hidden in the standard TFP growth measure.

This model brings another important issue of capital heterogeneity in growth accounting. First, when the access to credit is limited only to a subset of the economy, the rates of return to the same capital can be different between the intermediated sector and non-intermediated sector. Second, even within each sector, existence of fixed setup cost generates another kind of capital heterogeneity because the setup cost capital is sunk without being paid any positive instant return. These kinds of capital heterogeneity give us other kinds of caution on the use of aggregate production function and the standard growth accounting. The problem from the usual capital homogeneity assumption in understanding the economic growth in transition was noticed early, which is cogently stated by Schultz (1988) such that "the simplifying assumption that capital is homogeneous is a disaster to capital theory (Hicks, 1965), and ... is subject to serious doubts. $\cdots$ The dynamics of economic growth is afloat on capital inequalities because of the differences in rates of returns when disequilibria prevail, $\cdots$ Thus, one of the essential parts of economic growth is concealed by such aggregation." Banerjee and Duflo (2004) provide a review that cautions the use of aggregate production function for growth theory in various development contexts, including credit constraints. In the standard growth accounting, this capital heterogeneity effect can be hidden in the TFP growth occurred when the composition of the heterogeneous types of capital changes.

The above methodology of identifying the sources of the TFP growth was applied to Thailand, where enormous structural changes accompanied the rapid economic growth for the two decades 1976-1996. Standard growth accounting from the macro data suggests that capital accumulation was the major source of the total output growth, but at the same time the TFP growth was also the substantial source of growth in Thailand. We found that financial deepening, i.e., expansion of access to credit, played a key role in explaining the Thai TFP growth from the decomposition of either the simulated economy or the actual economy. Furthermore, combining the macro growth accounting results with the micro TFP growth decomposition results, we found that financial deepening and capital accumulation move together and explain both the growth-peak in the middle of 1980's and the gradual decline after 1991 of the Thai economy. The occupational shifts from traditional subsisters and laborers into entrepreneurs explained minor part of the TFP growth because the occupational transition itself was not substantial. In fact, this was also true in the actual data. The capital heterogeneity effect on the TFP growth were substantial only for the short initial periods in simulation. We also learned from simulation that the sectoral Solow residuals become important in explaining the TFP growth when the wage endogenously grows and also that its effect depends on relative factor income shares and can differ across sectors. In particular, the wage growth can contribute to reduce the sectoral Solow residual within the credit sector through the profit reduction. In the actual data, we could not separate the capital heterogeneity effect from the sectoral Solow residual effect because within-sector capital and setup cost data are not available. However, the remainder TFP growth term including these two effects indeed were substantial in the actual Thai data either only for the short initial periods or only when the Thai wage started to grow. Thus, the remainder TFP growth in the actual data shows exactly the same combined patterns of simulation.

For the rapidly growing economy with structural changes like Thailand, we could find the TFP growth in terms of financial deepening without presuming exogenous technical progress, from synthesizing the micro and macro data in the tight nexus between theory and data. Thus, the tendency of inferring the importance of technical change from the standard aggregate Solow residual seems indeed misleading. The industry-level disaggregate TFP growth may provide more precise estimate of productivity growth. However, note that we partitioned the economy by occupation and access to credit. All compositional effects from occupational shifts, financial deepening, and capital heterogeneity can be still alive even within the industry-level TFP growth. Thus, the same caution is still valid to the industry-level disaggregate TFP growth. Only by using the micro data, ideally in combination of household and firm data, together with the macro data can this problem be resolved. Explicit use of theory provides critical help for this.

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A Appendix: Estimation of Missing Observations

The data for labor share for the years earlier than 1980 and for the final year 1996 are not available. Thus, we fill the missing observations for labor share x_t by estimating a *AR(2)* model:

$$x_t = \lambda_0 + \lambda_1 x_{t-1} + \lambda_2 x_{t-2} + \varepsilon_t, \tag{65}$$

where the disturbance term ε_t is drawn from *i.i.d.* normal distribution $N(0, \sigma^{\varepsilon})$. Using the time-series sample between 1980 and 1995, the model is estimated and Table A.1 reports the estimates (with standard errors in parentheses). All coefficients are significant with p-values less than 0.001.

Table A.1. Estimated Parameters for *AR(2)* Model of Labor Share

λ_0	λ_1	λ_2	σ^{ε}
0.0773	1.5431	-0.7385	0.0093
(0.0035)	(0.1824)	(0.2257)	(0.0023)

The missing value for 1996 is predicted from 1995 and 1994 labor shares using the equation (65) at the above estimates. To get the missing labor shares before 1980, we need to re-formulate the model in terms of sum of lagged disturbance terms such that

$$x_t = \varphi(L)\lambda_0 + \varphi(L)\varepsilon_t,$$

where L indicates a lag operator and $\varphi(L)$ is the lag polynomial given by

$$\begin{aligned} \varphi(L) &= (1 - \lambda_1 L - \lambda_2 L)^{-1} \\ &\equiv \sum_{k=0}^{\infty} \varphi_k L^k. \end{aligned}$$

Note that $\varphi(L)\lambda_0 = \frac{\lambda_0}{1-\lambda_1 L - \lambda_2 L} = E(x)$ and $\varphi_k = \Lambda^k(1,1)$, i.e., the (1,1) element of the matrix Λ^k, which is a matrix powered by k times, where

$$\Lambda = \begin{bmatrix} \lambda_1 & \lambda_2 \\ 1 & 0 \end{bmatrix}$$

Here, we approximate the polynomial $\varphi(L)$ by the ninth-order.

The missing value of land share for 1996 is forecasted from the estimated *AR(2)* model y_t below:

$$y_t = \psi_0 + \psi_1 y_{t-1} + \psi_2 y_{t-2} + \nu_t, \tag{66}$$

where ν_t is drawn from *i.i.d.* normal distribution $N(0, \sigma^{\nu})$. We use the available time-series sample between 1972 and 1995. The estimates for land share are given in Table A.2. All coefficients are significant with p-values less than 0.06.

Table A.2. Estimated Parameters for *AR(2)* Model of Land Share

ψ_0	ψ_1	ψ_2	σ^{ν}
0.0011	1.7993	-0.8176	0.0020
(0.0004)	(0.1460)	(0.1253)	(0.0003)

The quality-adjusted labor index z_t shows a clear increasing trend. Thus, we estimate a trend-stationary model in logarithm of z_t:

$$\ln(z_t) = \delta_0 + \delta_1 t + \eta_t,$$

where η_t is drawn from *i.i.d.* normal distribution $N(0, \sigma^{\eta})$, using the available sample between 1980 and 1995. The estimates are given in Table A.3 below. All coefficients are significant with p-values less than 0.001. The missing values of the quality-adjusted labor index are filled at these estimates.

Table A.3. Estimated Parameters for Log-Trend-Stationary Model of Quality-adjusted Labor Index

δ_0	δ_1	σ^{η}	R^2
-39.550	0.0223	0.0330	0.9112
(3.556)	(0.0018)		

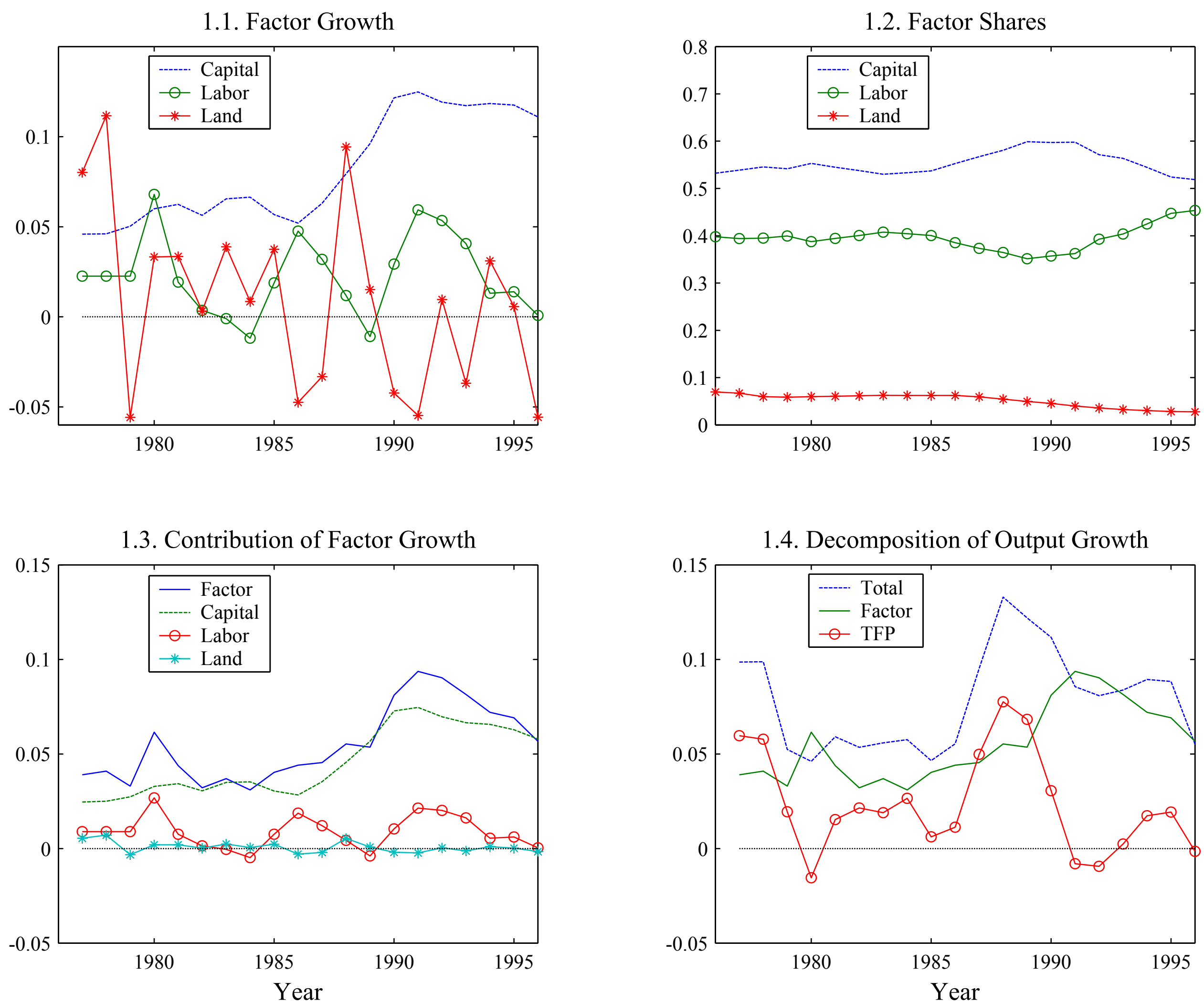

Figure 1. Growth Accounting in Thailand

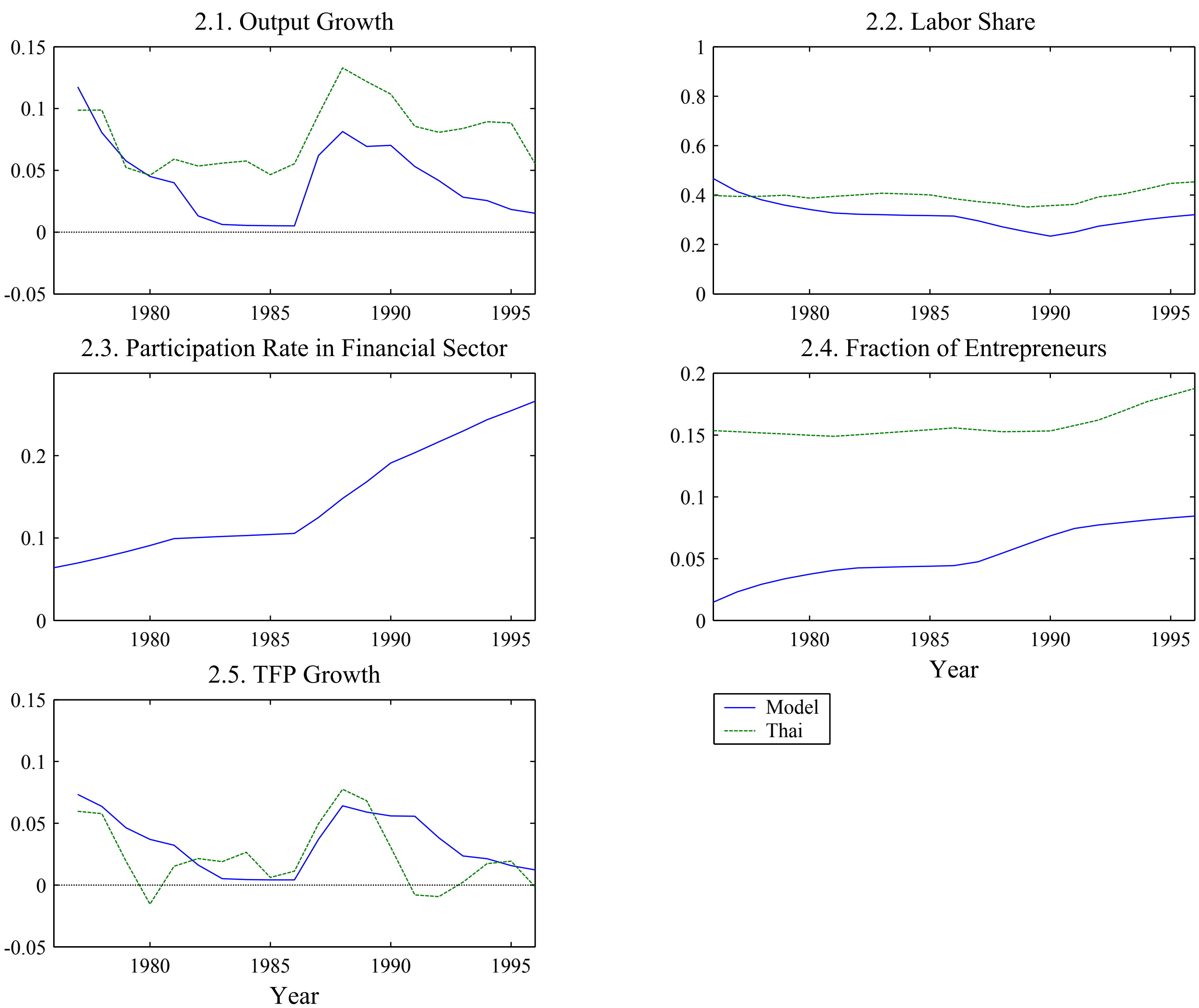

Figure 2. Aggregate Growth Dynamics

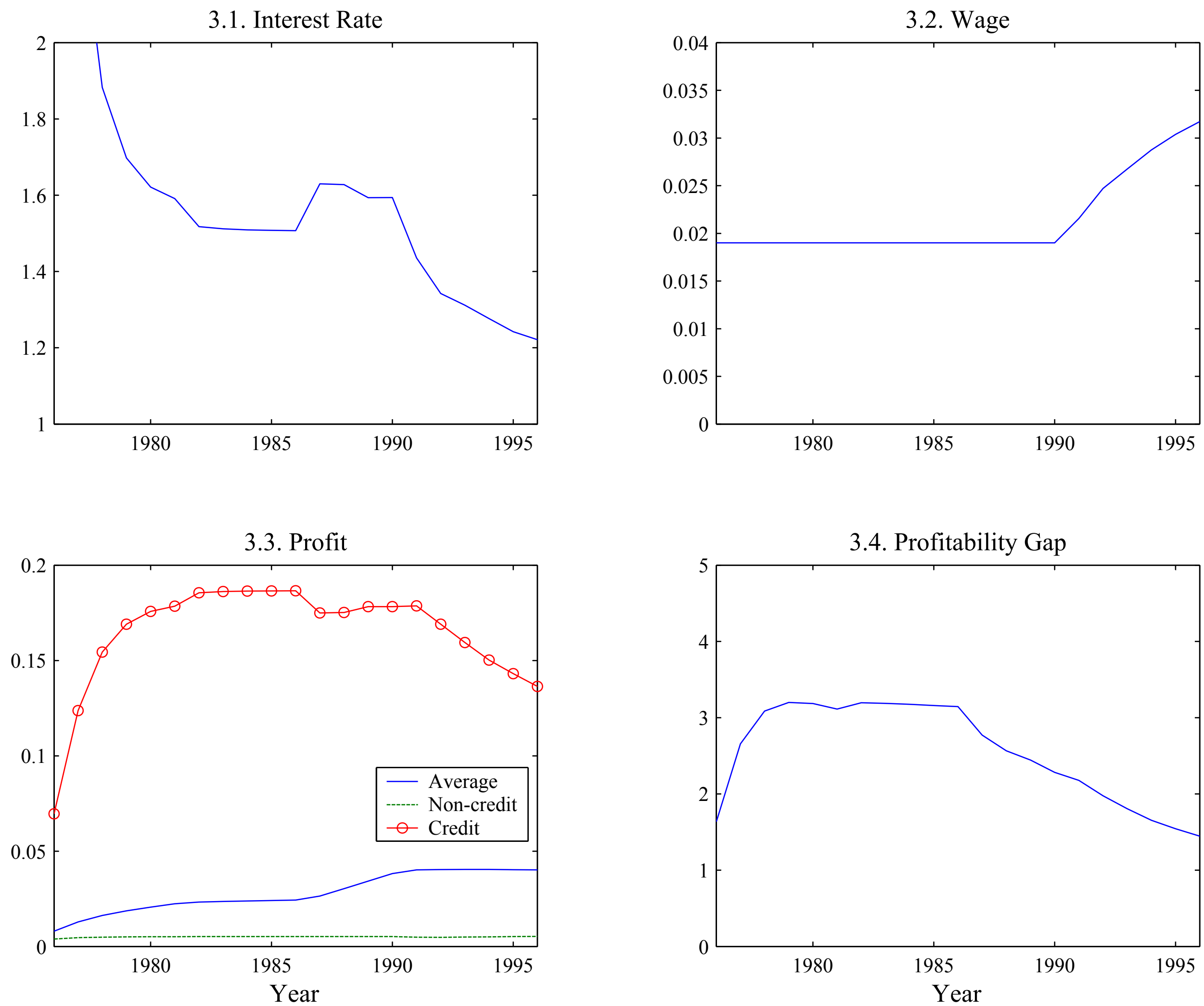

Figure 3. Simulated Factor Price Dynamics

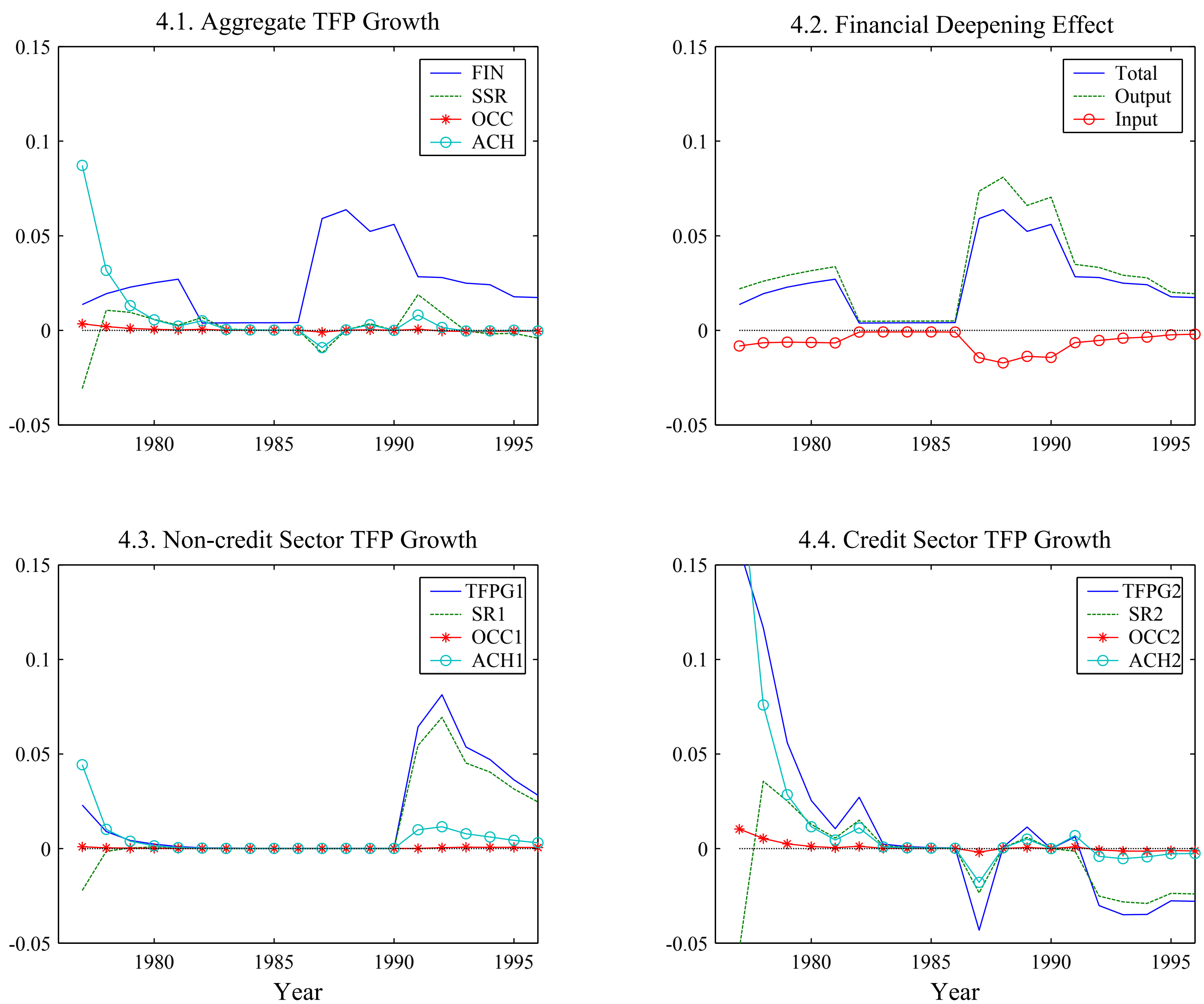

Figure 4. Decomposition of Simulated TFP Growth

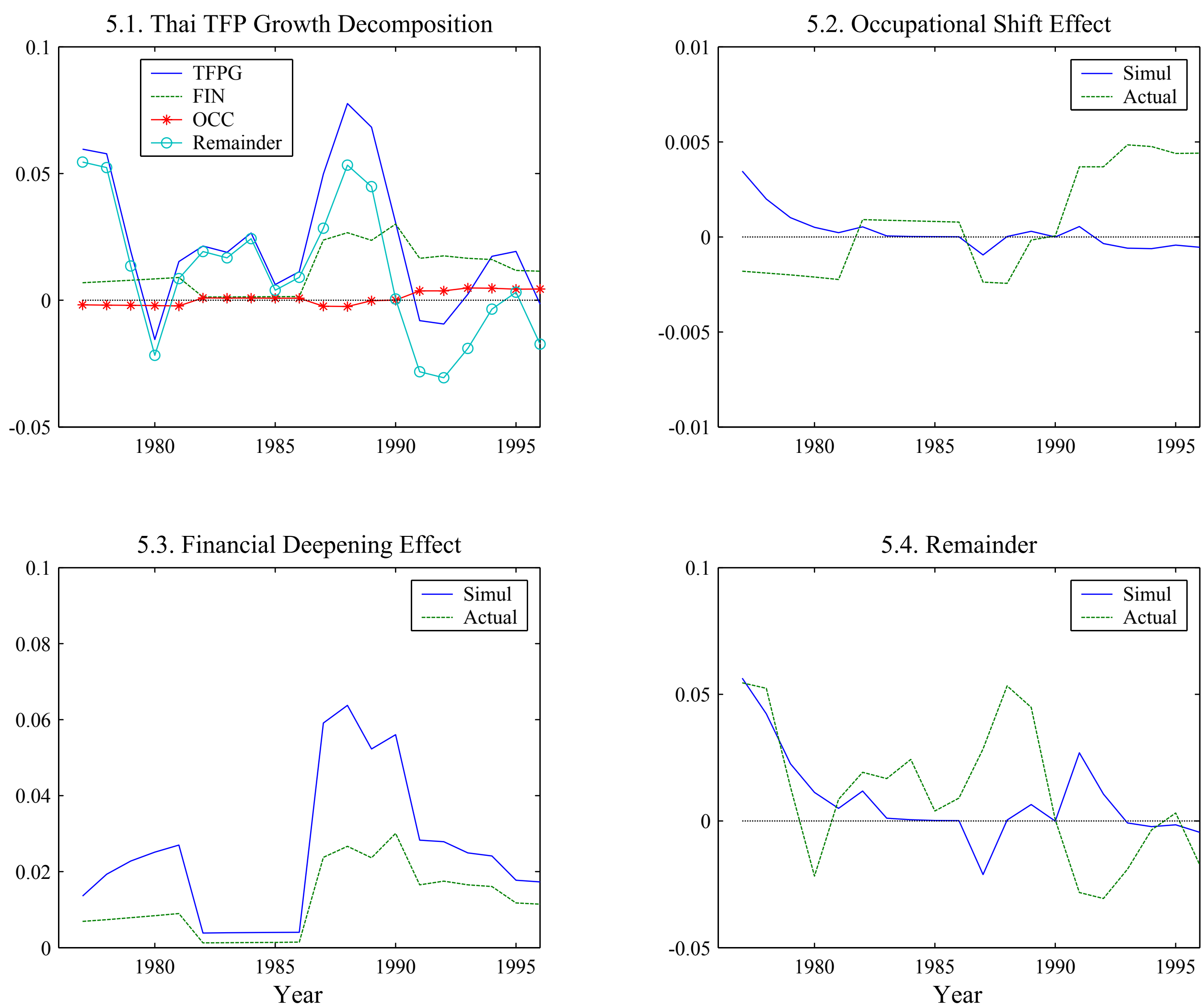

Figure 5. Sources of Actual Thai TFP Growth

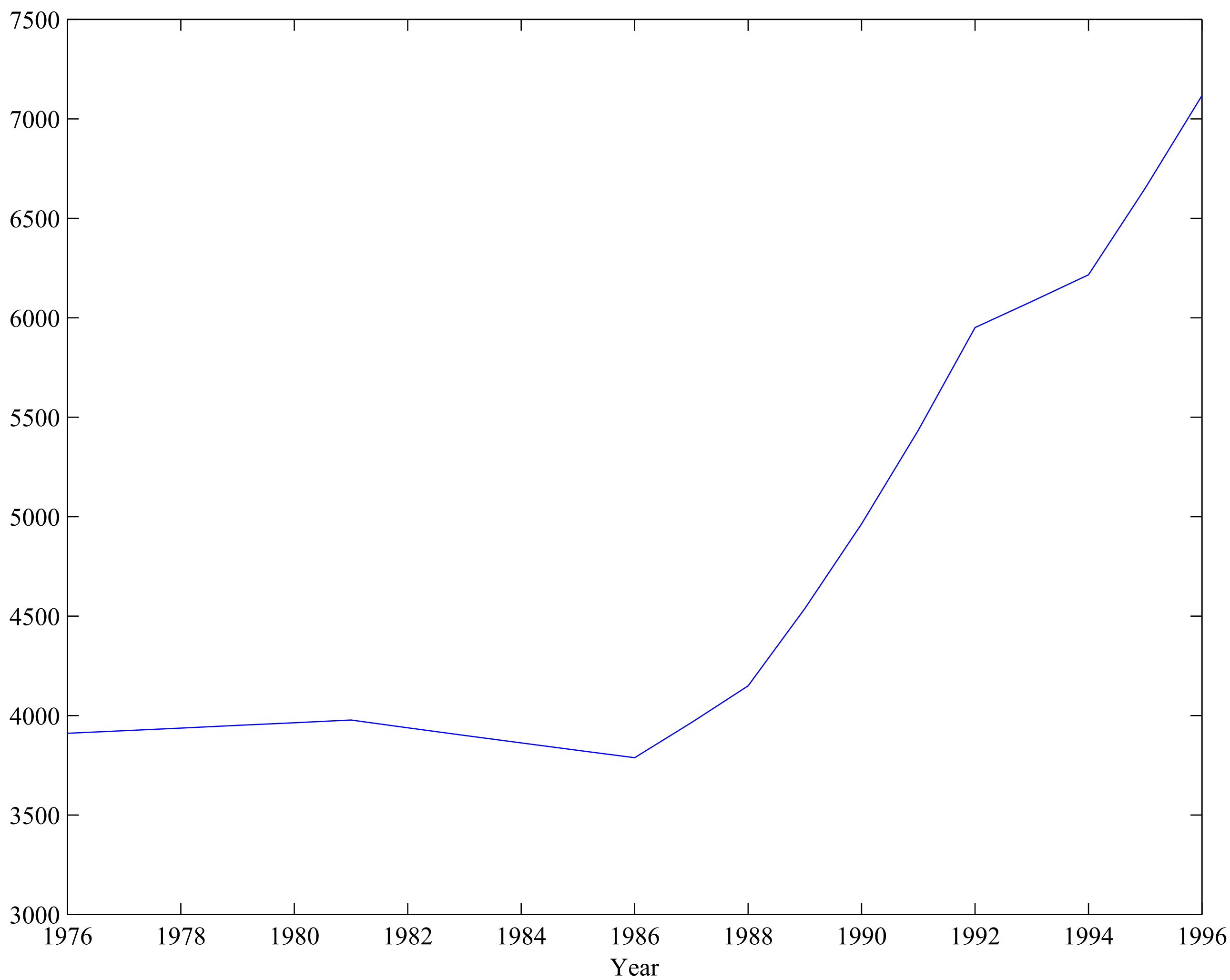

Figure 6. Thai Wage

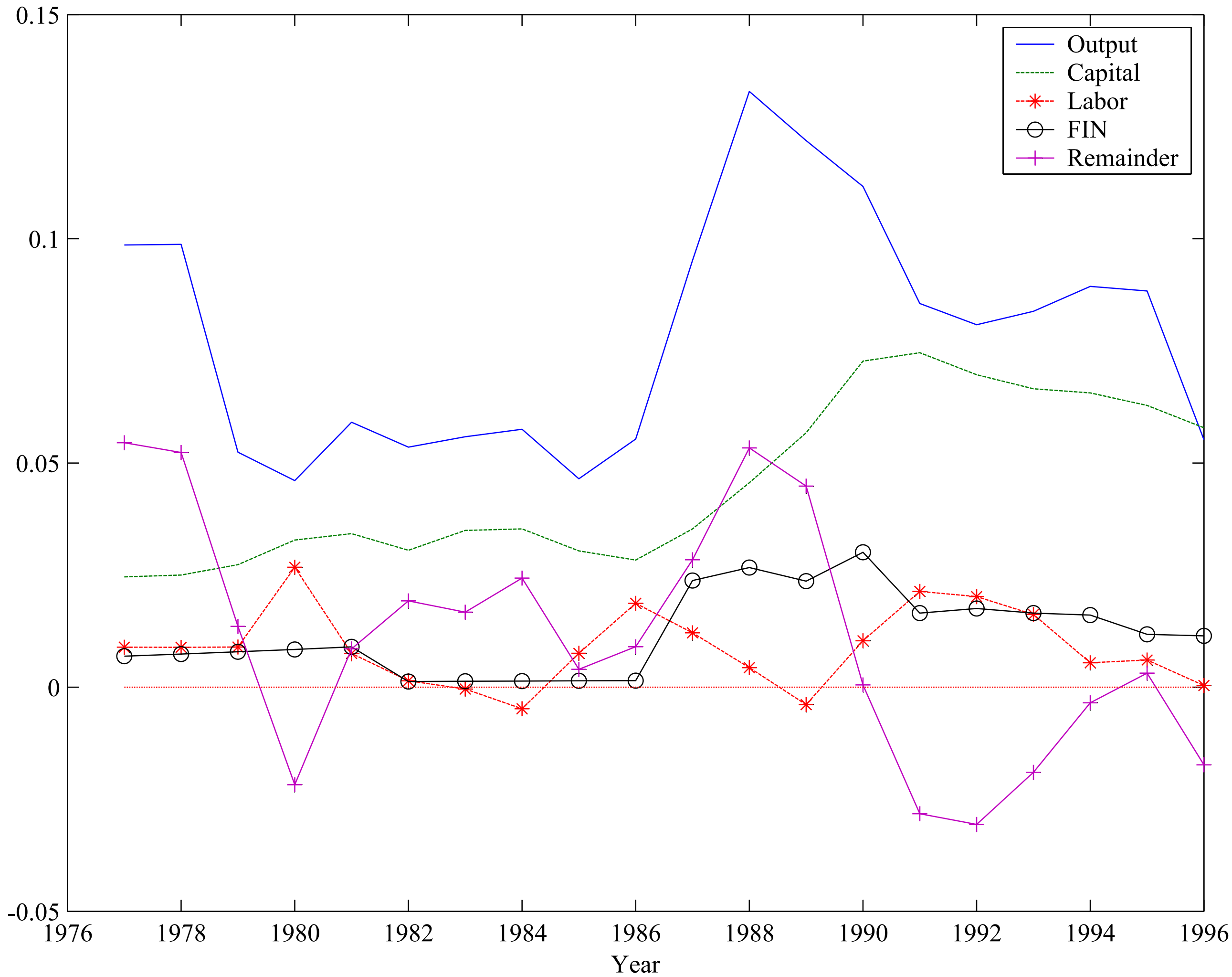

Figure 7. Sources of Growth in Thailand

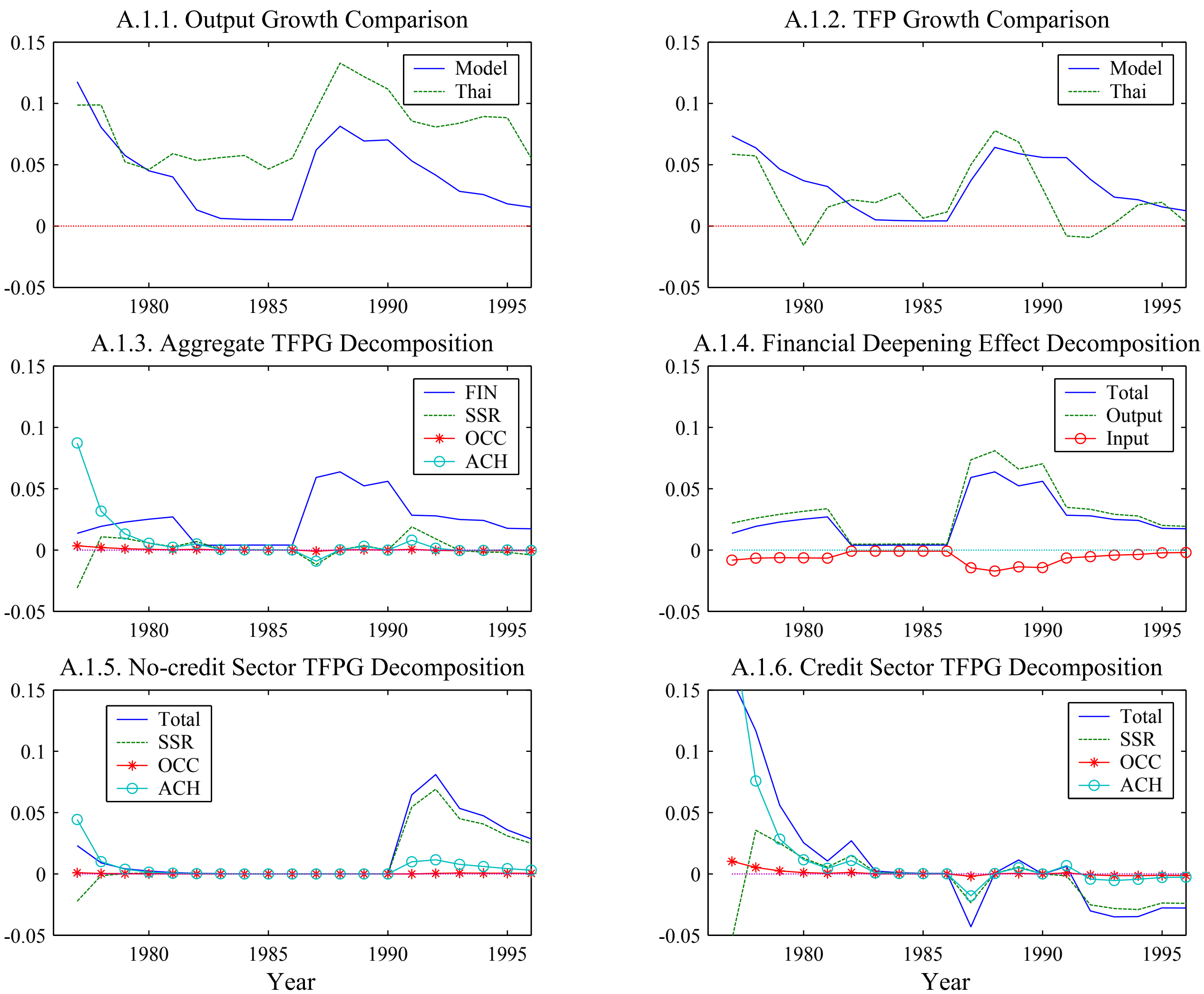

Figure A.1. Sigma at 0.0025

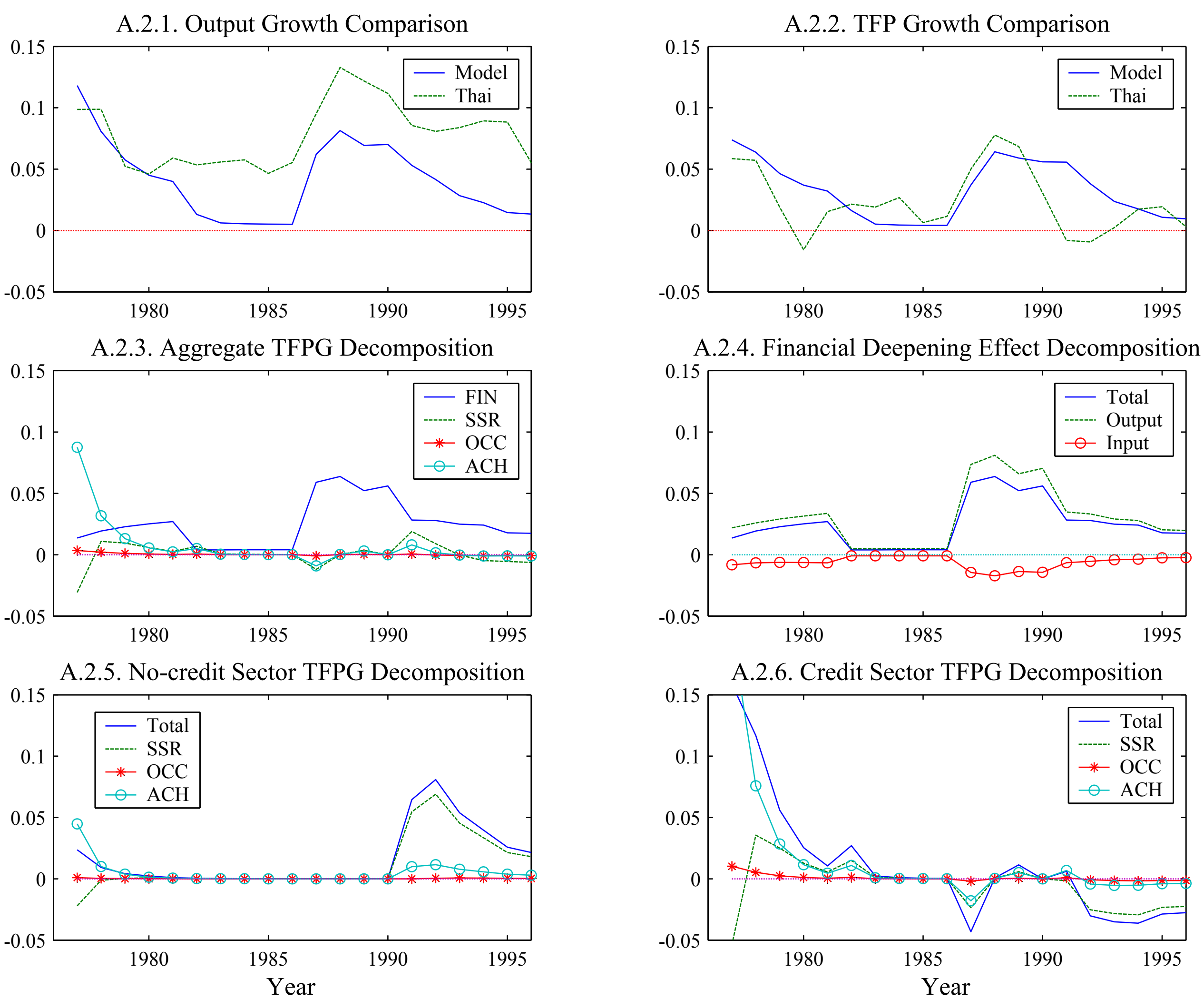

Figure A.2. Alpha at 1.300

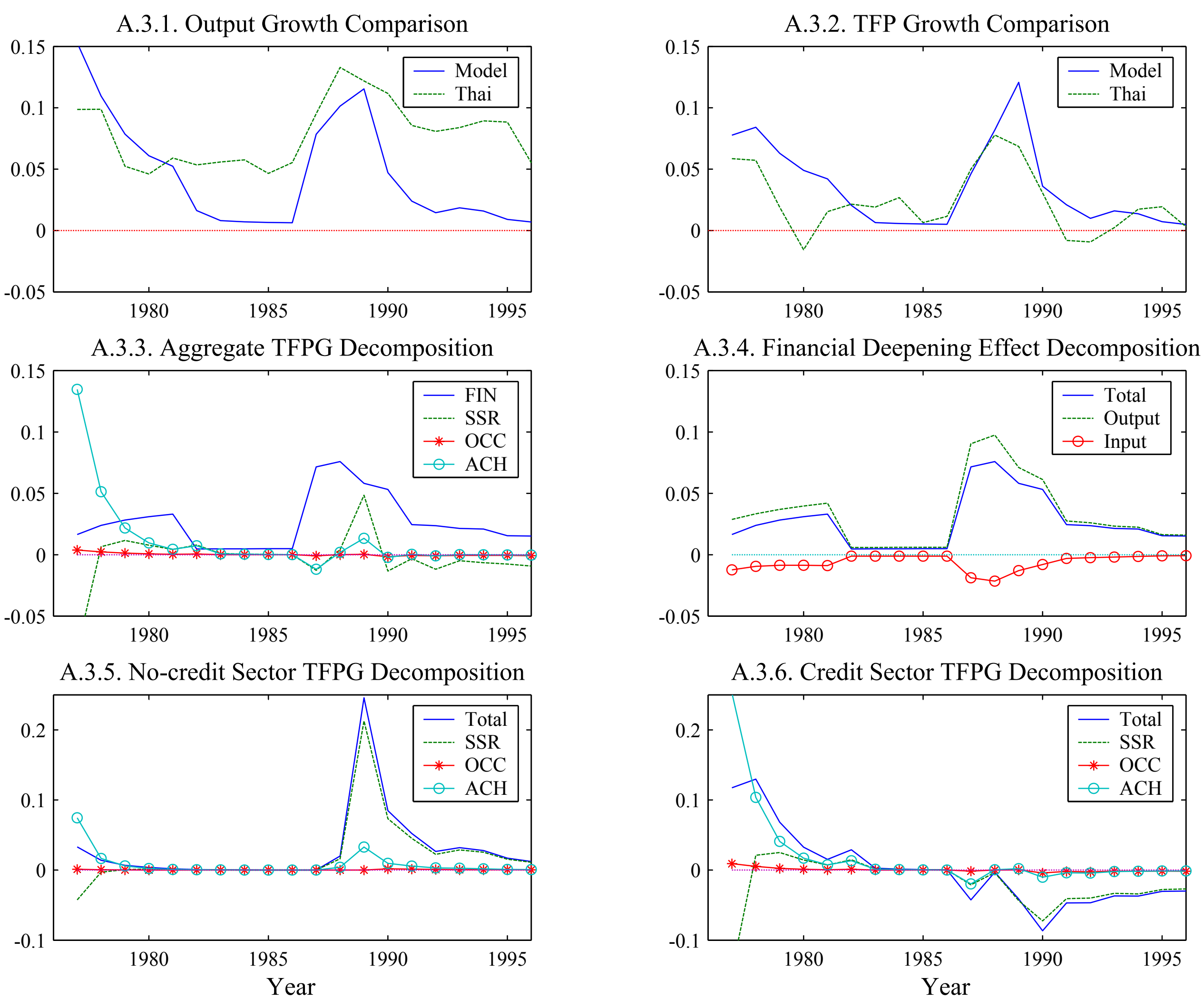

Figure A.3. Xi at 0.1100

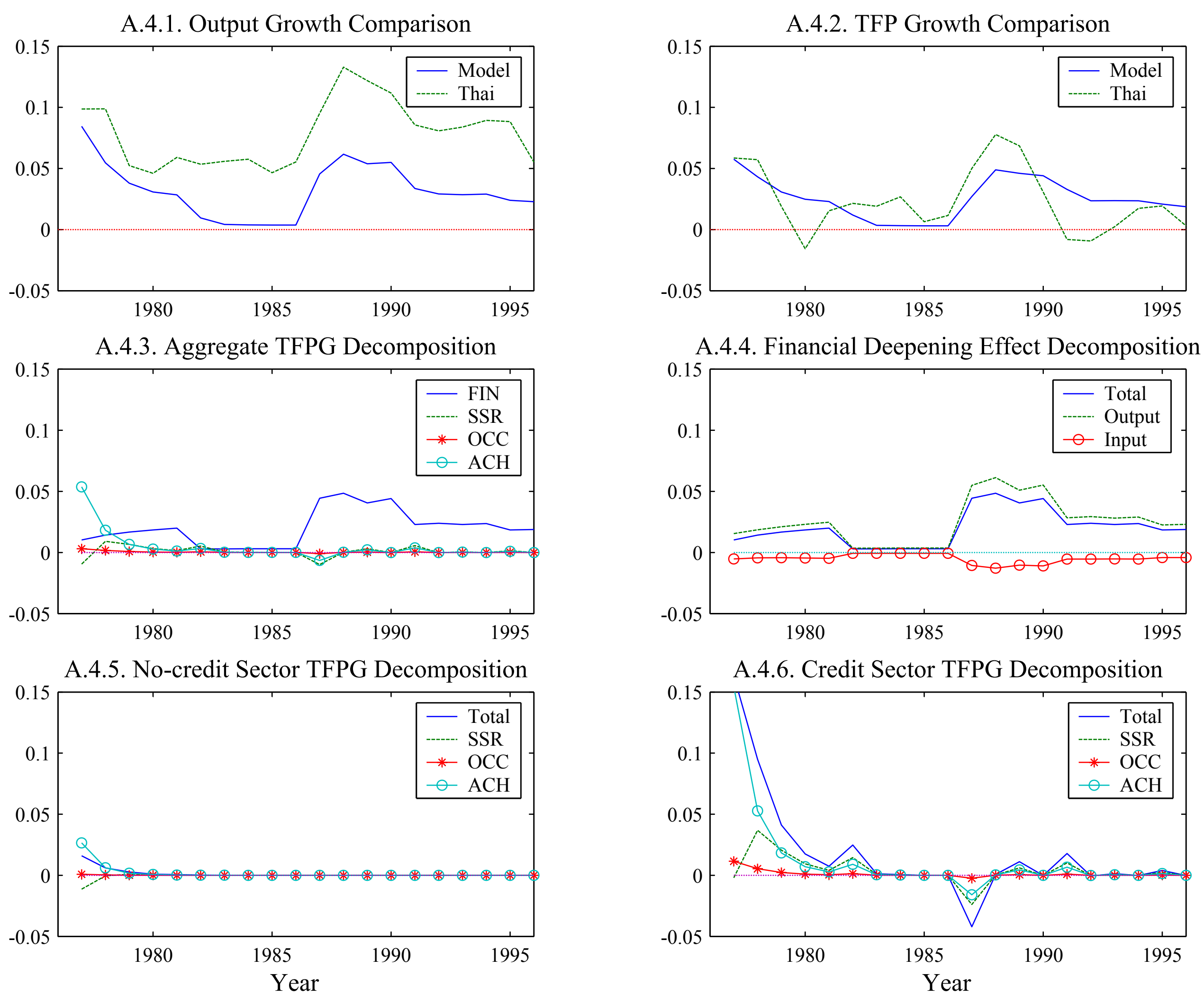

Figure A.4. Rho at 0.0080

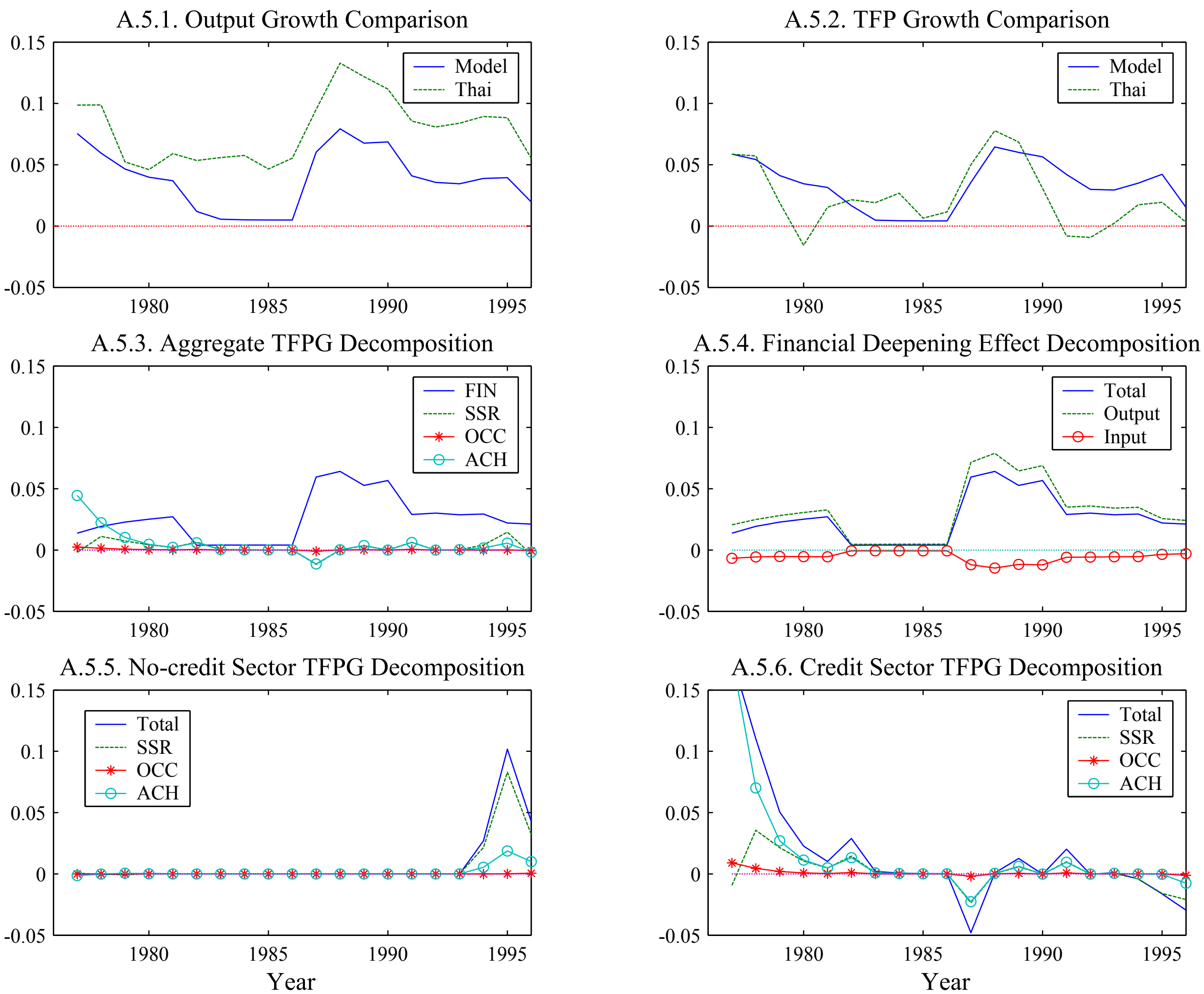

Figure A.5. Omega at 0.25

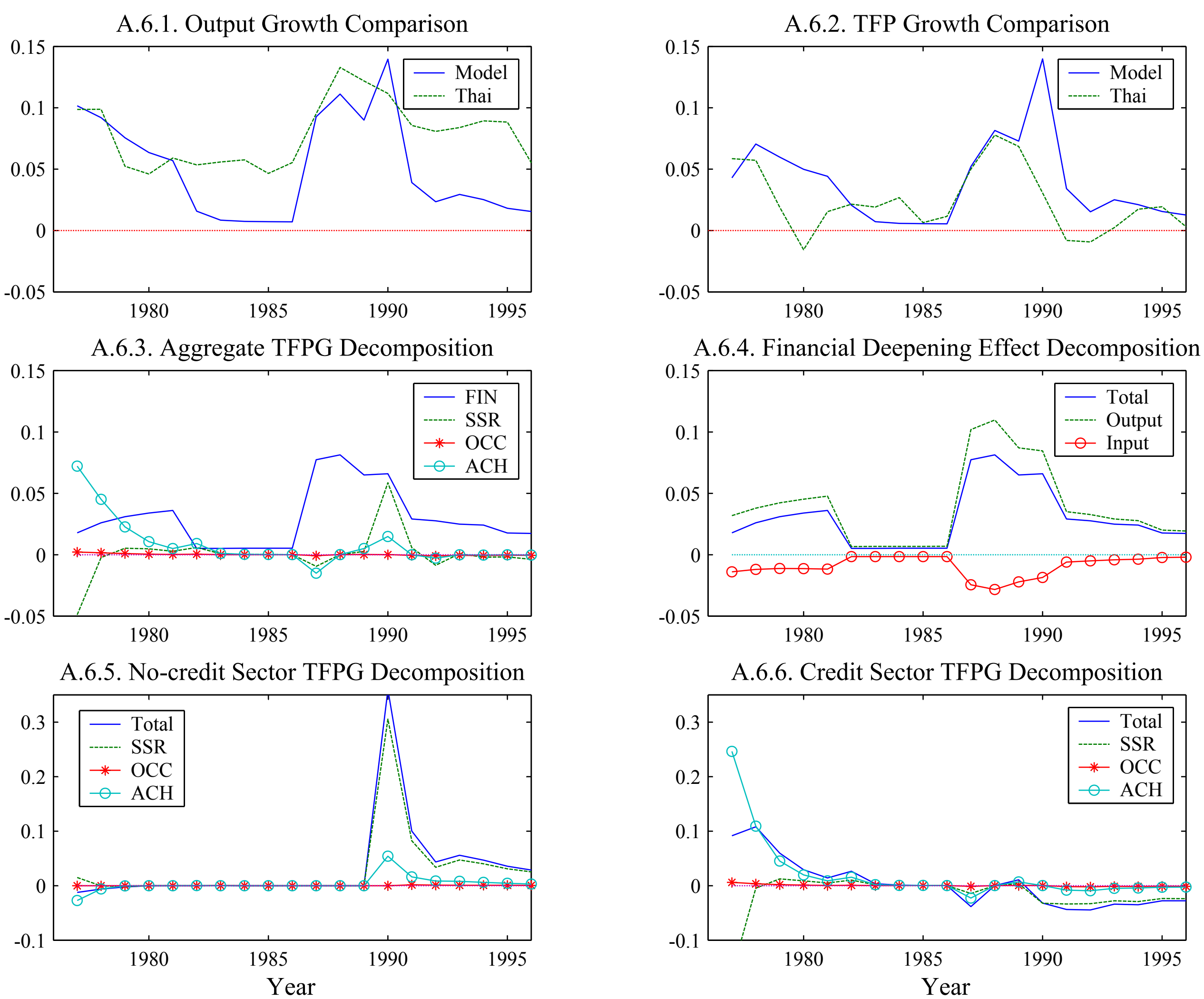

Figure A.6. Gamma at 0.0120