A Theory of Modern Transition Applied to Thailand

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Abstract

We consider a dual economy consisting of a traditional sector and a modern sector. Each sector uses sector-specific skills, which are acquired through experience and complement labor. There is exogenous productivity growth only in the modern sector, which attracts people toward that sector. The transition to the exclusive use of the modern sector occurs gradually, because experience and labor are complements within each sector. During transition, aggregate output follows an S-shaped path, eventually converging to the productivity growth of the modern sector. The endogenous evolution of the distribution of experience across sectors jointly drives (i) aggregate growth and (ii) inequality dynamics during transition. Using micro data from the Thai Socio-Economic Survey for 1976-1996, we partition the economy into traditional and modern sectors and estimate the deep parameters of the model, explicitly measuring the size of the sector-specific complementarity between labor and experience. We then simulate the model at the estimated parameters and report on the success of the model in explaining the dynamics of (i) average labor earnings, (ii) sectoral transition, (iii) inter-sectoral earnings inequality and (iv) intra-sectoral earnings inequality.

JEL: O11, O47, J31, O15

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1 Introduction

An emerging literature beginning with Lucas (2000) has argued that the proximate cause of the observed disparity in income levels across countries, is that today’s poor countries began the process of industrialization much later, and that this process is slow. This paper argues that a model of transition from traditional to modern sector production can jointly provide a useful theory of why (i) industrialization occurs at different times and at different rates, and (ii) how income inequality within countries evolves during the course of industrialization.

Our model of transition focuses on the role of a particular form of human capital: sector-specific skills which are acquired through experience, and which complement labor within each sector. We assume there is exogenous productivity growth only in the modern sector which thereby attracts workers from the traditional sector to that sector. As in Chari and Hopenhayn (1991), the complementarity of labor and sector-specific experience means that entry into the modern sector by young agents who supply labor, is limited by the stock of old agents who supply experience. Meanwhile, today’s young entrants in turn determine tomorrow’s stock of experience.\(^1\) The transition to the exclusive use of modern sector production occurs gradually, and the speed and the slope of the transition path depend on the initial distribution of experience across sectors. An implication of the model is that despite a constant productivity growth in the modern sector, aggregate output can remain stagnant for a long while, and then accelerates before decelerating, generating an S-shaped transition path.

Aggregate output growth is driven by the endogenous evolution of the distribution of experience across sectors, combined with exogenous productivity growth in the modern sector. Under conventional development accounting exercises, all of this aggregate output growth would enter into aggregate total factor productivity (TFP) growth. In this sense, our model provides a theory of TFP, as posited by Prescott (1998). Kehoe and Prescott (2002) document the importance of TFP in explaining within-country growth experiences. Regarding the sources of TFP differences, they postulate policy-oriented conjectures based on informed guesses, concluding that “absent careful micro studies at firm and industry levels, we can only conjecture as to what these policies are,” calling for micro evidence. This paper attempts to provide such micro evidence for the sources of TFP. While we agree that

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\(^1\)Chari and Hopenhayn (1991) consider steady states in an economy with a constant arrival of new technologies which each require specific skills. We consider out of steady state dynamics across two technologies where the modern technology has a constant productivity growth rate. Beaudry and Francois (2004) highlight the existence of multiple steady states in a two technology economy, when there is no productivity growth in the modern sector.
differences in policy may explain TFP differences over space and time, we think that before rushing into a discussion of policies, TFP differentials can alternatively be derived from differences in some fundamental conditions. In our model, the candidate fundamental condition is the initial distribution of experience across modern and traditional sectors. We then evaluate quantitatively how much a model with no policy arguments can explain.

Although we do not conduct development accounting, the model has an implication for such cross-country exercises. Klenow and Rodríguez-Clare (1997) show that adding aggregate experience in measuring human capital plays virtually no role in accounting for cross-country income differences. This is further confirmed by Caselli (2003). Our model suggests that the relevant variable regarding experience in explaining cross-country income differences, is the distribution of sector-specific experience rather than aggregate experience. Incorporating the distribution of sector-specific experience in measuring human capital, will reduce the size of the TFP differences in development accounting.²

Our model of transition jointly provides a framework to analyze within country inequality dynamics. After partitioning the economy into traditional and modern sectors, we can document systematic differences in earnings both across sectors and within sectors, and their evolution over time. Within each sector, the complementarity between labor and experience implies that the relative abundance of experienced labor compared to raw labor determines the sector-specific earnings premium. Within each sector, individual earnings depend not only on the level of individual experience but also on the aggregate ratio between labor and experience. In this way, the demographic composition of each sector and its evolution over time determine both inter-sectoral and intra-sectoral inequality levels. Thus, our model provides a micro foundation for the growth-inequality nexus through a particular aspect of human capital: the distribution of experience across modern and traditional sectors.

The empirical importance of demographic composition across industries and occupations in explaining changes in the wage structure has been well documented for U.S., including by Freeman (1979), and more recently by Katz and Murphy (1992) and Murphy and Welch (1992). During the period of these studies, 1963-1989, the U.S. underwent significant demographic changes due to the baby boom generation at the aggregate level, and due to structural transformation at the industry levels. However, these demographic changes are likely to be larger and more ordered in developing

²Manuelli and Seshadri (2005) pursue a different way of reducing the size of TFP in development accounting in relation to human capital. They show that by endogenizing the schooling decision, a large fraction of cross-country income differences can be explained by differences in the quality of human capital.
countries which are undergoing transition from traditional to modern production. The model provides an underlying mechanism that captures this effect of sector-specific demographic change on inequality.

Indirect evidence for other underlying aspects of our model exist in the literature. Foster and Rosenzweig (2004) show the importance of productivity growth in the manufacturing sector for agricultural development and the evolution of rural inequality for rural growth in India during 1968-1999. This supports the assumption of exogenous productivity growth in the modern sector. Kim and Topel (1995) find that for South Korea during 1970-1990, the rapid growth of the manufacturing sector was accomplished through new entrants to the workforce (who then stay in that sector for the rest of their careers) rather than through shifts of existing old workers from agriculture. This supports the assumption of sector-specific skills acquired through experience during transition.

There are three main ways to partition a transition economy under structural transformation: (i) agriculture versus non-agriculture, (ii) rural versus urban, and (iii) traditional versus modern. Kuznets (1955) emphasized population shifts from agriculture to non-agriculture. Most of the recent literature that highlights the importance of structural transformation in understanding cross-country income differences follows this partition (Gollin, Parente and Rogerson (2002), Hansen and Prescott (2002), Ngai (2003) and Parente and Prescott (2004)). Todaro (1969) is an early treatment of transition and labor productivity via rural-urban migration. Lucas (2004) provides an updated discussion illuminating the role of human capital.

In this paper, we focus on the third type of structural transformation: transition from traditional to modern production. This does not necessarily coincide with, though is related to, the other types of structural transformation. Our paper is closest to the strand of dual-economy models, featuring transition as a population shift from traditional to modern sector, pioneered by Lewis (1954) and Ranis and Fei (1961).

Given that sector-specificity plays an important role, the primary challenge of our quantitative exercise is the sectoral partitioning itself. Quantitative attempts of the dual-economy partition in relation to models have rarely been performed because there are no direct counterparts in the data that identify the “modern” sector from the “traditional” sector. We attempt to measure the dual-

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3 In contrast to the assumptions of the existence of unlimited surplus labor and an imposed inter-sectoral gap in marginal productivity of labor in original dual-economy models, we consider all inputs to be priced at competitive margins in both traditional and modern sectors. Despite this, we can still generate take-off transition dynamics, the typical feature of conventional dual-economy models.
economy partition by use of both our model and the micro data. Once the partition is identified, we measure the parameters of the model including the size of the sector-specific complementarity between labor and experience.

We apply our model to explain the aggregate and disaggregate dynamics of labor earnings of Thailand for the two-decade period between 1976 and 1996. Although our model has implications for cross-country income differences, here we pursue the growth dynamics of a single country for two reasons. First, the Thai economy experienced rapid growth with enormous structural transformation in various dimensions. This allows us to observe a wide spectrum of modern transition for the two decades under consideration. In particular, Thai average earnings shows a take-off feature during transition as typical dual-economy models predict. Average earnings were stable for the first decade 1976-1986, then took off, while modern transition was steady and rapid over the entire two decade period 1976-1996.

Second, Thailand provides us with a rich set of micro data that can be used to select the parameter values of the model from an explicit estimation. Specifically, using nationally representative household survey data from Thailand, we can measure key parameters like the sector-specific complementarity between experience and labor, which have not been conducted previously in the growth empirics literature. Thus, simulating the model with a tight link to the actual data for a single country allows us to learn not only about the appropriate parameter space for the model, but also how the various general equilibrium forces of the model work through. This will lay the ground for future analysis of other countries as well as for future cross-country studies. In sum, Thailand provides a good example of a dual economy under transition to which we can bring a model of transition to actual data, and explicitly measure the quantitative importance of the model in explaining the modernization process and the associated evolution of growth and inequality.

We estimate almost all the deep parameters of the model using the within-sector earnings relationships implied by the model. We then simulate the model at the chosen parameters and compare the simulated dynamics with the actual data. We report on the model success in explaining the dynamics of (i) aggregate earnings growth, (ii) sectoral transition, (iii) inter-sectoral earnings inequality, and (iv) intra-sectoral earnings inequality for the Thai economy.

We find the model captures the take-off feature of the aggregate earnings path. It also captures well the S-shaped transition of cohort share of modern sector. The model explains the overall increasing
trend in the inter-sectoral earnings inequality found in the data. Finally, the model predicts the observed changes in experience-earnings profiles, in particular the large drop in experience premium in the traditional sector between 1976 and 1996.

The paper is organized as follows. Section 2 describes the model. Section 3 describes the data. Section 4 discusses the procedure of structural estimation. Section 5 discusses the simulation results. Section 6 concludes.

2 Model

Consider a two-period overlapping generations economy with constant population.\(^4\) Lifetime preferences are,

\[ u = c_1 + \beta c_2, \quad \beta \in (0, 1) \quad (1) \]

Since utility is linear in consumption, the equilibrium interest factor is \( R = \frac{1}{\beta} \). The lifetime budget constraint is given by,

\[ c_1 + \beta c_2 = y_1 + \beta y_2 \quad (2) \]

Production occurs in two sectors that produce a homogenous good, a traditional sector and a modern sector. Let \( G(L_{T,t}, E_{T,t}), \gamma_t^4 X F(L_{M,t}, E_{M,t}) \) denote efficiency units of labor in the traditional sector and modern sector respectively. Aggregate labor earnings in period \( t \) is given by,\(^5\)

\[ LY_t = G(L_{T,t}, E_{T,t}) + \gamma_t^4 X F(L_{M,t}, E_{M,t}) \quad (3) \]

The efficiency units of labor in each sector are a constant returns to scale function of raw labor \( L_{k,t} \) and sector specific experience \( E_{k,t} \), for \( k \in \{T, M\} \). Define \( \varpi_T \equiv G(1, 0) \) and \( \varpi_M \equiv F(1, 0) \).

In each sector, raw labor and experience are complements,

\[ \frac{\partial^2 G(L_{T,t}, E_{T,t})}{\partial L_{T,t} \partial E_{T,t}} \geq 0 \quad \text{and} \quad \frac{\partial^2 F(L_{M,t}, E_{M,t})}{\partial L_{M,t} \partial E_{M,t}} \geq 0 \quad (4) \]

The only identifying assumption of the modern sector is that there are sustained exogenous increases in productivity for that sector only \( \gamma > 1 \).\(^6\) We assume \( \beta \gamma < 1 \).\(^7\)

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\(^4\) We generalize the model to \( s \) period overlapping generations later in the paper.

\(^5\) Later, we show how this function is derived from a general production function with physical capital in each sector.

\(^6\) We think the assumption of exogenous technical progress is appropriate for late industrializing economies who have access to technologies developed elsewhere by early industrializing economies. In particular, our model does not attempt to explain the origins of the Industrial Revolution.

\(^7\) Despite the arrival of new technologies we assume experience is transferable across technologies within the modern sector. In our empirical work we find modern sector production is more intensive in physical and human capital. One can think of modern experience as being specific to production with high physical and human capital intensity.
Each agent is endowed with one unit of labor when he is young. When old, this agent is endowed with \( \lambda \) units of labor and \( \lambda \) units of experience specific to the sector he worked in when young.\(^8\) \( \lambda \) denotes the depreciation factor of both labor and experience supplied by each worker. The consideration of depreciation does not affect the qualitative results, but it plays an important role in the quantitative analysis. Let \( N_t, M_t \) denote the measure of young agents who enter the modern and traditional sectors respectively in period \( t \). The resource constraints are,

\[
L_{T,t} = M_t + \lambda M_{t-1} \\
E_{T,t} = \lambda M_{t-1} \\
L_{M,t} = N_t + \lambda N_{t-1} \\
E_{M,t} = \lambda N_{t-1} \\
1 = M_t + N_t
\]

\( \lambda \in (0, 1], M_{-1} \in [0, 1], N_{-1} \in [0, 1] \) given.

The resource constraints can be simplified to,

\[
L_{T,t} = 1 + \lambda - L_{M,t} = 1 - N_t + \lambda(1 - N_{t-1}) \\
E_{T,t} = \lambda - E_{M,t} = \lambda(1 - N_{t-1})
\]

The state of the economy in period \( t \) is \( N_{t-1} \). The initial state \( N_{-1} \) is given.

Define \( g \left( \frac{L_{T,t}}{E_{T,t}} \right) \equiv \frac{G(L_{T,t}, E_{T,t})}{E_{T,t}} \). Then, the marginal product of traditional labor is \( g' \left( \frac{L_{T,t}}{E_{T,t}} \right) \). The marginal product of traditional experience is \( \phi \left( \frac{L_{T,t}}{E_{T,t}} \right) \equiv g \left( \frac{L_{T,t}}{E_{T,t}} \right) - g' \left( \frac{L_{T,t}}{E_{T,t}} \right) \left( \frac{L_{T,t}}{E_{T,t}} \right) \). Since labor and experience are complements, \( g' \left( \frac{L_{T,t}}{E_{T,t}} \right) \) is falling in \( \frac{L_{T,t}}{E_{T,t}} \), and \( \phi \left( \frac{L_{T,t}}{E_{T,t}} \right) \) is increasing in \( \frac{L_{T,t}}{E_{T,t}} \).

Define \( f \left( \frac{L_{M,t}}{E_{M,t}} \right) \equiv \frac{F(L_{M,t}, E_{M,t})}{E_{M,t}} \). Then, the marginal product of modern labor is \( \gamma^t X f' \left( \frac{L_{M,t}}{E_{M,t}} \right) \). The marginal product of modern experience is

\[
\gamma^t X \pi \left( \frac{L_{M,t}}{E_{M,t}} \right) \equiv \gamma^t X \left[ f \left( \frac{L_{M,t}}{E_{M,t}} \right) - f' \left( \frac{L_{M,t}}{E_{M,t}} \right) \frac{L_{M,t}}{E_{M,t}} \right].
\]

Since labor and experience are complements, \( \gamma^t X f' \left( \frac{L_{M,t}}{E_{M,t}} \right) \) is falling in \( \frac{L_{M,t}}{E_{M,t}} \), and \( \gamma^t X \pi \left( \frac{L_{M,t}}{E_{M,t}} \right) \) is increasing in \( \frac{L_{M,t}}{E_{M,t}} \).

In period \( t \), the lifetime earnings of an agent entering the traditional sector when he is born is,

\[
g' \left( \frac{L_{T,t}}{E_{T,t}} \right) + \beta \lambda \left[ g' \left( \frac{L_{T,t+1}}{E_{T,t+1}} \right) + \phi \left( \frac{L_{T,t+1}}{E_{T,t+1}} \right) \right]
\]

\(^8\) Instead of simply assuming young and old agents supply different inputs, as in Chari and Hopenhayn (1991), we split up the inputs into labor and experience. This provides a more natural characterization of complementarity between young and old workers when we consider an \( s \)-period overlapping generations model for simulation purposes.
In period $t$, the lifetime earnings of an agent entering the modern sector when he is born is,

$$
\gamma^t X \left[ f'(\frac{L_{M,t}}{E_{M,t}}) + \beta \lambda \gamma \left[ f'(\frac{L_{M,t+1}}{E_{M,t+1}}) + \pi \left(1 + \frac{1}{\lambda}\right)\right]\right]
$$

If there were no sectoral reallocation of workers,

$$
N_{t-i} = N_t \in (0,1) \forall t - i \leq t
$$

$$
\Rightarrow \frac{L_{T,t}}{E_{T,t}} = \frac{L_{M,t}}{E_{M,t}} = 1 + \frac{1}{\lambda}
$$

When we observe $\frac{L_{T,t}}{E_{T,t}} < (1 + \frac{1}{\lambda}) \Rightarrow \frac{L_{M,t}}{E_{M,t}} > (1 + \frac{1}{\lambda})$ and vice versa.

We assume that the lifetime earnings of an agent working in the traditional sector is weakly lower than that in the modern sector when there is no sectoral reallocation of workers. i.e.,

$$
\text{Condition A} : \quad g' \left(1 + \frac{1}{\lambda}\right) + \beta \lambda \left[g'\left(1 + \frac{1}{\lambda}\right) + \phi \left(1 + \frac{1}{\lambda}\right)\right] \leq \gamma^t X \left[ f'\left(1 + \frac{1}{\lambda}\right) + \beta \lambda \gamma \left[f'\left(1 + \frac{1}{\lambda}\right) + \pi \left(1 + \frac{1}{\lambda}\right)\right]\right]
$$

(7)

Note if Condition A is true for $t = 0$, it is true for $\forall t \geq 0$.

We do not model the economy before the "Industrial Revolution". The Industrial Revolution is defined as having occurred in the first historical year that $\gamma > 1$. Using this definition, we can pin down $X_{IR}$,

$$
g' \left(1 + \frac{1}{\lambda}\right) + \beta \lambda \left[g'\left(1 + \frac{1}{\lambda}\right) + \phi \left(1 + \frac{1}{\lambda}\right)\right] = X_{IR} \left[ f'\left(1 + \frac{1}{\lambda}\right) + \beta \lambda \left[f'\left(1 + \frac{1}{\lambda}\right) + \pi \left(1 + \frac{1}{\lambda}\right)\right]\right]
$$

(8)

Note this is a sufficient for Condition A in (7).

### 2.1 Equilibrium

A competitive equilibrium consists of a sequence of sectoral entry decisions $\{N_t\}_{t=0}^{\infty}$, such that in every period $t$,

(i) every agent earns wages equal to his marginal product,

(ii) new born agents choose which sector to work in for the rest of their lives, and how much to consume each period to maximize their lifetime utility (1) given the interest factor $R$, wages implied by (3), the distribution of labor across sectors in period $t$, $\{N_t, N_{t-1}\}$, the distribution of labor across sectors in periods $t+i$, $\{N_{t+i}\}_{i=1}^{\infty}$, and budget constraint (2),
(iii) the resource constraints (6) are satisfied.

In equilibrium, ex ante identical young agents in period $t$ choose with sector to work in for the rest of their lives according to,

$$\max \left\{ g' \left( \frac{L_{T,t}}{E_{T,t}} \right) + \beta \lambda \left[ g' \left( \frac{L_{T,t+1}}{E_{T,t+1}} \right) + \phi \left( \frac{L_{T,t+1}}{E_{T,t+1}} \right) \right], \gamma^t X \left[ f' \left( \frac{L_{M,t}}{E_{M,t}} \right) + \beta \lambda \gamma \left( f' \left( \frac{L_{M,t+1}}{E_{M,t+1}} \right) + \pi \left( \frac{L_{M,t+1}}{E_{M,t+1}} \right) \right) \right] \right\}$$

If young agents enter both sectors in period $t$, $N_t \in (0,1)$. Using the resource constraints and the definitions of labor and experience from (5),

$$g' \left( 1 + \frac{1 - N_t}{\lambda (1 - N_{t-1})} \right) + \beta \lambda \left[ g' \left( 1 + \frac{1 - N_{t+1}}{\lambda (1 - N_t)} \right) + \phi \left( 1 + \frac{1 - N_{t+1}}{\lambda (1 - N_t)} \right) \right] = \gamma^t X \left[ f' \left( 1 + \frac{N_t}{\lambda N_{t-1}} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{N_{t+1}}{\lambda N_t} \right) + \pi \left( 1 + \frac{N_{t+1}}{\lambda N_t} \right) \right] \right]$$

**Lemma 1** Let $T$ denote the first period at which the entire population is working in the modern sector. Given $N_{t-1} = 1$, then $N_{t+i} = 1 \ \forall i \geq 0$, and $t = T$.

**Proof in Appendix.**

If all young agents enter the modern sector in period $t - 1$, $N_{t-1} = 1$, using Lemma 1 the participation constraint is,

$$g' \left( 1 \right) + \beta \lambda \left[ g' \left( 1 \right) + \phi \left( 1 \right) \right] \leq \gamma^{t-1} X \left[ f' \left( 1 + \frac{1}{\lambda N_{t-2}} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{1}{\lambda} \right) + \pi \left( 1 + \frac{1}{\lambda} \right) \right] \right]$$

Equations (10) and (11) characterize a system of difference equations in $N_t$ of order 2.

**Proposition 1** Given the initial state $N_{-1},$

(i) there exists a unique equilibrium transition path with $T < \infty$,

(ii) the population of the modern sector never falls $N_{t-1} \leq N_t$, and

(iii) $N_t$ is increasing in $N_{-1}$, for $\forall t \geq 0,

(iv) $T$ is decreasing in $N_{-1}$.

**Proof in Appendix.**
Proposition 1(ii) states that the population of the modern sector is increasing throughout transition, which implies the population of the traditional sector is always falling. Proposition 1(iii) and 1(iv) state transition is faster when the share of experienced agents in the modern sector is larger in the initial period.

In our simulations, we encounter the following outcome: during transition, lifetime earnings are first rising slower than $\gamma$, then rising faster than $\gamma$. Once transition is complete, lifetime earnings grows at rate $\gamma$. Thus, the simulated outcomes describe an S-shaped path of lifetime earnings over the time series.

To understand this result intuitively, suppose there is no complementarity in the modern sector so $\frac{\partial^2 F(L_{M,t},E_{M,t})}{\partial L_{M,t} \partial E_{M,t}} = 0$. Then, the labor-experience ratios do not determine lifetime earnings in the modern sector in the participation constraint equation (10). In this case, the lifetime earnings grows at the steady state rate $\gamma$ during and after transition as in the Solow economy.

Next, suppose there is no complementarity in the traditional sector so $\frac{\partial^2 G(L_{T,t},E_{T,t})}{\partial L_{T,t} \partial E_{T,t}} = 0$. Then, the labor-experience ratios do not determine lifetime earnings in the traditional sector in the participation constraint equation (10). This implies lifetime earnings are constant in the traditional sector. In this case, lifetime earnings are constant during transition up to period $T - 2$, then they converge to the steady state lifetime earnings path by period $T$. Once transition is compete, lifetime earnings grow at the steady state rate $\gamma$. In general, when there is complementarity in both sectors, the lifetime earnings follows the S-shaped pattern described above, and its growth path is humped shaped.

**Proposition 2** During transition (i.e. for $t < T$),

(i) If lifetime earnings is rising: the population of the traditional sector is falling at a faster rate, $\frac{1-N_t}{1-N_{t-1}} > \frac{1-N_{t+1}}{1-N_t}$.

(ii) If lifetime earnings is first rising slower than $\gamma$, then rising faster than $\gamma$: the population growth of the modern sector is single peaked, $\exists Q \in \{1, ..., T-1\}$, such that $\frac{N_t}{N_{t-1}} < \frac{N_{t+1}}{N_t}$ for all $t < Q$ and $\frac{N_t}{N_{t-1}} \geq \frac{N_{t+1}}{N_t}$ for all $t \geq Q$.

**Proof in Appendix.**
The average earnings in each sector in period \( t \) is given by,

\[
Traditional : \ G \left( 1, \frac{1}{1 - N_t} \right) \left( \frac{N_t}{N_{t-1}} + 1 \right) \left( \frac{1 - N_t}{1 - N_{t-1}} + 1 \right) + \lambda \\
Modern : \ \gamma^t X F \left( 1, \frac{1}{N_t} \right) \left( \frac{N_t}{N_{t-1}} + 1 \right) \left( \frac{N_t}{N_{t-1}} + 1 \right)
\]

When the population growth in either sector is falling, average wages in that sector must be rising. Thus, from Proposition 2(i), when lifetime earnings is rising, average wages are rising in the traditional sector. In the modern sector, average earnings are affected by two forces. When population growth is increasing this tends to decrease average earnings. Meanwhile, productivity growth tends to increase the average earnings over time. Only when population growth is decreasing can we conclude that average modern earnings are increasing.

The ratio of experienced worker earnings to inexperienced worker earnings (i.e. the experience premium) in each sector in period \( t \) is given by,

\[
Traditional : \ \lambda \left( 1 + \frac{\phi}{g'} \left( 1 + \frac{1 - N_t}{N_{t-1}} \right) \right) \\
Modern : \ \lambda \left( 1 + \frac{\pi}{f'} \left( 1 + \frac{N_t}{N_{t-1}} \right) \right)
\]

The experience premium is positively correlated to the population growth rate in each sector.

### 2.2 Welfare

The allocation of workers across technologies in the competitive equilibrium coincides with the allocation of a social planner with objective function,

\[
\max_{\{N_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t Y_t \ \text{s.t.} \ (3) \ \text{and} \ (5) \tag{12}
\]

Specifically, the first order conditions of this problem equal the participation constraints (10) and (11). Thus, competitive equilibrium outcomes maximize the present discounted value of aggregate output.

### 2.3 Comparative Statics

Here we demonstrate the qualitative role of initial differences in the share of experienced labor in the modern sector (the state variable) on lifetime earnings and average earnings growth. In particular, we
show how this is affected by the relative degree of complementarity between the modern and traditional sectors. In a two period overlapping generations setting, the initial share of modern experience is a single number, which would be a distribution of experience across sectors with more than two periods.

The transition dynamics of the model crucially hinge on the sector-specific complementarity between labor and experience. To quantify the magnitudes of the complementarity, we parameterize the sectoral production functions $G$ and $F$ by the following CES forms,

$$\begin{align*}
\text{Traditional} & : 
G(L_{T,t}, E_{T,t}) = \left[ \alpha_T L_{T,t}^{\rho_T} + (1 - \alpha_T) E_{T,t}^{\rho_T} \right]^{\frac{1}{\rho_T}} \\
\text{Modern} & : 
F(L_{M,t}, E_{M,t}) = \left[ \alpha_M L_{M,t}^{\rho_M} + (1 - \alpha_M) E_{M,t}^{\rho_M} \right]^{\frac{1}{\rho_M}}
\end{align*}$$

where $\rho_T < 1$, $\rho_M < 1$, $0 < \alpha_T < 1$, and $0 < \alpha_M < 1$. The elasticities of substitution between labor and experience are measured by $\frac{1}{1-\rho_T}$ and $\frac{1}{1-\rho_M}$, respectively for traditional and modern sectors. The lower the values of $\rho_T$ and $\rho_M$, the greater the complementarity between labor and experience. At the limit value of $\rho_T$ and $\rho_M$ at unity, labor and experience are perfect substitutes with relative shares being governed by the parameters $\alpha_T$ and $\alpha_M$ alone, and experience premia are measured by $(1 - \alpha_T)$ and $(1 - \alpha_M)$. We may consider the parameters $\alpha_T$ and $\alpha_M$ as controlling the pure experience premium in the absence of complementarity.

Assuming people work 40 years, 1 period in our two period overlapping generations model corresponds to 20 years. The calibrated parameters are,

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Note</th>
</tr>
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<tbody>
<tr>
<td>$\beta$</td>
<td>0.045</td>
<td>$\simeq (0.86)^{20}$ from real annual interest rate 16%, within range of Thai data</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>1.3</td>
<td>$\simeq (1.013)^{20}$ average productivity growth UK, 1900-2000</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.6</td>
<td>$\simeq (0.975)^{20}$ consistent with estimates for Thailand we report</td>
</tr>
</tbody>
</table>

We set modern sector productivity growth equal to aggregate productivity growth of the UK, a frontier economy, assuming (i) modern technologies are developed in such frontier economies and (ii) the UK completed its modern transition before 1900. $X$ is set to satisfy $X = X_{IR}$ from (8), so the initial period is the Industrial Revolution which we consider to be around 1820.

For this demonstrative exercise, we highlight the role of relative complementarity in the production function. In Experiment 1, complementarity is higher in the modern sector. In Experiment 2, complementarity is higher in the traditional sector.

<table>
<thead>
<tr>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
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</table>

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We first report outcomes in Experiment 1. [Figure 1] shows the evolution of lifetime earnings with different initial shares in the modern sector, \( N_{-1} \). Two economies with \( N_{-1} = 0.1, N_{-1} = 0.001 \) have negligible differences in lifetime earnings at the initial period, but the first economy is 3 times richer 100 years later. However, 160 years after the initial period, all economies are equally rich.

The pattern of divergence then convergence of average earnings relative to the steady state economy (defined as \( N_{-1} = 1 \)), implies economies which experience a take-off of earnings later, enjoy faster absolute increases in earnings once they take-off. This pattern of growth is consistent with Parente and Prescott (2000), who document that countries that achieved a certain level of income ($2000 in 1990 US dollars) later in history, were able to double their income in a far shorter period than countries that achieved this level of income earlier in history.

Outcomes under Experiment 2 as shown in [Figure 2], are very different. The difference in lifetime earnings across countries with different initial shares is significantly reduced, although the S-shaped pattern of convergence still remains. Convergence in lifetime earnings occurs more rapidly under Experiment 2.

Since we are not aware of any studies which report the technology parameters for the traditional and modern sector production functions specified, we cannot assess the validity of the parameters \( \{ \alpha_T, \alpha_M \} \) and \( \{ \rho_T, \rho_M \} \) used above. We measure these key parameters using the model and micro data from Thailand, in the estimation and simulation sections.

### 2.4 Aggregate Output versus Aggregate Earnings

As before, \( G(L_{T,t}, E_{T,t}), \gamma^t XF(L_{M,t}, E_{M,t}) \) denote efficiency units of labor, and let \( K_{T,t}, K_{M,t} \) denote physical capital in the traditional and modern sectors respectively. In each sector, output is produced subject to constant returns to scale in all inputs. Aggregate output in period \( t \) is given by,

\[
\bar{Y}_t = \bar{Y}_T [G(L_{T,t}, E_{T,t}), K_{T,t}] + \bar{Y}_M \left[ \gamma^t \bar{X}F(L_{M,t}, E_{M,t}), K_{M,t} \right] \\
≡ \tilde{y}_T \left( \frac{K_{T,t}}{G(L_{T,t}, E_{T,t})} \right) G(L_{T,t}, E_{T,t}) + \tilde{y}_M \left( \frac{K_{M,t}}{\gamma^t \bar{X}F(L_{M,t}, E_{M,t})} \right) \gamma^t \bar{X}F(L_{M,t}, E_{M,t}) \\
≡ \tilde{y}_T (k_{T,t}) G(L_{T,t}, E_{T,t}) + \tilde{y}_M (k_{M,t}) \gamma^t \bar{X}F(L_{M,t}, E_{M,t})
\]  

(13)

When the marginal product of capital is constant at \( R = \frac{1}{\beta} \), the ratio of capital to efficiency units...
of labor is constant, and is implicitly given by,

\[ R = \ddot{y}_T (k_T^*) = \ddot{y}_M (k_M^*) \]

This in turn implies the labor share of output in each sector is a constant,

\[ s_T (k_T^*) \equiv \frac{\ddot{y}_T (k_T^*) - \ddot{y}_T (k_T^*) k_T^*}{\ddot{y}_T (k_T^*)} \]

\[ s_M (k_M^*) \equiv \frac{\ddot{y}_M (k_M^*) - \ddot{y}_M (k_M^*) k_M^*}{\ddot{y}_M (k_M^*)} \]

Then, we can express aggregate labor earnings as,

\[ \tilde{L}Y_t = s_T (k_T^*) \ddot{y}_T (k_T^*) G (L_{T,t}, E_{T,t}) + s_M (k_M^*) \ddot{y}_M (k_M^*) \gamma_t \tilde{X} F (L_{M,t}, E_{M,t}) \]

From here if we renormalize the units of output by \( s_T (k_T^*) \ddot{y}_T (k_T^*) \), and define \( X \equiv \frac{s_M (k_M^*) \ddot{y}_M (k_M^*)}{s_T (k_T^*) \ddot{y}_T (k_T^*)} \), we get the formula for aggregate labor earnings \( \tilde{L}Y_t \), used in the main analysis.

Consider the aggregate labor share of output, which can be written as,

\[ \frac{\tilde{L}Y_t}{Y_t} = s_T (k_T^*) \frac{G (L_{T,t}, E_{T,t}) \gamma_t \tilde{X} F (L_{M,t}, E_{M,t})}{s_T (k_T^*) \ddot{y}_T (k_T^*)} \]

When everyone is producing in the traditional sector this share is \( s_T (k_T^*) \), and when everyone is producing in the modern sector this share is \( s_M (k_M^*) \). Depending on whether \( s_T (k_T^*) \lessgtr s_M (k_M^*) \), output grows faster or slower than earnings. In particular, if the capital share is higher in the modern sector, aggregate output growth will be higher than aggregate earnings growth during transition.

### 2.5 S-period Model

We now consider a general \( s \)-period overlapping-generations model for \( 2 \leq s < \infty \), which will be used in our estimation and simulation of the model. Lifetime preferences are,

\[ u = \sum_{j=0}^{s-1} \beta^j c_j, \ \beta \in (0, 1) \]

The lifetime budget constraint is now given by,

\[ \sum_{j=0}^{s-1} \beta^j c_j = \sum_{j=0}^{s-1} \beta^j y_j \]

The sectoral production functions remain the same as in the two-period model.
Each agent who has been in the workforce for \( i \) periods is endowed with \( \lambda^i \) units of labor and \( i\lambda^i \) units of experience specific to the sector he joined when entering the workforce. Let \( N_t, M_t \) denote the measure of workforce entrants who enter the modern and traditional sectors respectively in period \( t \). \( N_{t-i} \) denotes the measure of agents in with \( i \) periods of experience in the modern sector at date \( t \).

The resource constraints at date \( t \) are given by,

\[
L_{M,t} = \sum_{i=0}^{s-1} \lambda^i N_{t-i} \quad (18)
\]
\[
E_{M,t} = \sum_{i=0}^{s-1} i\lambda^i N_{t-i} \quad (19)
\]
\[
L_{T,t} = \sum_{i=0}^{s-1} \lambda^i M_{t-i} \quad (20)
\]
\[
E_{T,t} = \sum_{i=0}^{s-1} i\lambda^i M_{t-i} \quad (21)
\]
\[
M_{t-i} = 1 - N_{t-i}, \forall i \quad (22)
\]

The state variable at date \( t \), is now the entire distribution of experience in the modern sector over the experience cohorts \( \{N_{t-i}\}_{i=1}^{s-1} \). The initial condition \( \{N_{-i}\}_{i=1}^{s-1} \) is given.

The lifetime earnings of an agent born at \( t \), entering the traditional sector or modern sector respectively are given by,

Traditional:

\[
\sum_{j=0}^{s-1} (\beta \lambda)^j \left[ f' \left( \frac{L_{T,t+j}}{E_{T,t+j}} \right) + j \phi \left( \frac{L_{T,t+j}}{E_{T,t+j}} \right) \right]
\]

Modern:

\[
\gamma t X \sum_{j=0}^{s-1} (\beta \lambda)^j \left[ f' \left( \frac{L_{M,t+j}}{E_{M,t+j}} \right) + j \pi \left( \frac{L_{M,t+j}}{E_{M,t+j}} \right) \right]
\]

If there were no sectoral reallocation of workers, the modern shares are constant, implying the labor-experience ratio is constant such that,

\[
N_{t-i} = N_t \in (0, 1) \forall t - i \leq t
\]

\[
\Rightarrow \frac{L_{T,t}}{E_{T,t}} = \frac{L_{M,t}}{E_{M,t}} = \frac{\sum_{i=0}^{s-1} \lambda^i}{\sum_{i=0}^{s-1} i\lambda^i} = \frac{1 - \lambda^s}{1 - \lambda} = \frac{(1 - \lambda^s)(1 - \lambda)}{\lambda - \lambda^s - (s - 1) \lambda^s(1 - \lambda)} \equiv l^*
\]
When we observe $\frac{L_{T,t}}{E_{T,t}} < l^* \Rightarrow \frac{L_{M,t}}{E_{M,t}} > l^*$ and vice versa.

Condition A is now replaced by Condition A’,

\[
\text{CONDITION A’} : \quad \sum_{j=0}^{s-1} (\beta \lambda)^j \left[ g'(l^*) + j \phi(l^*) \right] \leq \gamma^j X \sum_{j=0}^{s-1} (\beta \lambda)^j \gamma^j \left[ f'(l^*) + j \pi(l^*) \right] \quad \text{when} \quad \frac{L_{T,t}}{E_{T,t}} = \frac{L_{M,t}}{E_{M,t}} = l^*, \forall t
\]

$X_{IR}$ is given by,

\[
\sum_{j=0}^{s-1} (\beta \lambda)^j \left[ g'(l^*) + j \phi(l^*) \right] = X_{IR} \sum_{j=0}^{s-1} (\beta \lambda)^j \gamma^j \left[ f'(l^*) + j \pi(l^*) \right] \quad \text{(25)}
\]

In the Appendix, we outline the equilibrium construction procedure for this generalized model.

3 Data

We use the Thai Socio-Economic Survey (SES) for the 1976-1996 period, a \textit{nationally representative} household survey conducted by the Thai National Statistical Office. Eight rounds of repeated cross-sections were collected for this period (1976, 1981, 1986, 1988, 1990, 1992, 1994, and 1996), using clustered random sampling, stratified by geographic regions over the entire country. The sampling unit is household. The sample size varies depending on the year from 10,897 to 25,208 by households and 45,138 to 93,886 by individuals.

The SES records rich information on income variables and socioeconomic characteristics not only at the household level but also at the individual level for all household members. Total income is decomposed into its sources of wage, profits, property income, and transfer income. We convert the nominal income variables in the data into real terms in 1990 baht value using the CPI indices differentiated by five geographic regions (Bangkok and its Metropolitan vicinity region, Central region, Northern region, Northeast Region, and South region).

The socioeconomic characteristics of the SES include sex, age, region and community type of residence, years of schooling, occupation, socioeconomic class, working status (employer, self-employed, employee, family worker, unemployed, or inactive), type of enterprise if running a business, and industry sector. In particular, types of household enterprises are disaggregated into the two-digit level and occupational activities into the three-digit level.

The relevant concept of income of our model is \textit{earnings} rather than all-inclusive income. The disaggregated data of income combined with the individual working status data from the SES allow us
to sort out the earned income (i.e. wage income for employed workers and profit income for employers and self-employed people) from the total income to construct the earnings variable. We include only economically active people, (neither unemployed nor inactive people according to the work status variable) who indeed report earnings. People who live only on property income or transfer income are excluded. The size of the selected sample is 165,579 individuals for all years.

[Figure 3] documents how the Thai aggregate labor earnings accelerated during this period, enjoying a take-off around the mid-1980s. Using the rich information of individual characteristics from the SES, we identify traditional and modern sectors as specified by the model such that only the modern sector enjoys positive exogenous productivity growth. The detailed procedure of the partition will be discussed immediately below in the Estimation section. [Figure 4] displays the evolution of the share of the workforce in the modern sector in Thailand. Clearly, the period under consideration was one of significant transition for the Thai economy. The modern share of the workforce increased from 26 percent to 41 percent during the two decades. Comparing the two figures, Thai average earnings were stable for the first decade and then took off only in the second decade, while modernization was steady and rapid over the entire two decade period.

The aggregate modern shares in [Figure 4] are calculated from the cohort entry data. [Figure 5] displays the shares of workers across experience groups measured from the SES at different years over the sample period. We measure experience by age minus years of schooling minus six as is done in the labor literature. This obviously bears measurement errors in representing work experience. However, given the lack of the data on true work experience, we follow this convention of the labor literature that suggests this approximation is tolerable. One of the findings of Kim and Topel (1995) is that the reallocation of workers across sectors during industrialization is realized through new cohorts who stay in the sector after entry. Since we do not have panel data at the individual level, we cannot directly confirm that entrants into each sector remain in that sector for the rest of their lives as is predicted by the model. Without any changes in entry and exit across sectors, we should observe a single upward-sloping line when we overlay them across years. The data suggest that they are indeed upward-sloping each year with some exceptions for the very old cohorts. Furthermore, they are very closely aligned across years. Thus, the data seems to show a consistent pattern with the prediction of the model. We take the average value of modern shares of a given cohort across overlapping years, and then calculate the Lowess smoothing line for the period between 1919 and 1996 to get the modern
cohort share data. The line labeled as “Lowess” shows the smoothed cohort entry data.

During this transitional growth period, inter and intra sectoral differences in earnings have also evolved. Figure 6 shows that the ratio of average earnings of modern to traditional sector increased from 1.5 in 1976 to 2 by 1992, and then declined to 1.8 in 1996. Figure 7 and Figure 8 show the evolution of the experience-earnings profiles over time for modern and traditional sectors, respectively. Each year we observe a hump-shaped profile in the modern sector but this is much less so in the traditional sector. Over time, the experience premium in each sector, our measure of intra-sectoral inequality has changed quite a bit. In both sectors, the experience premium increased between 1976 and 1988 and then fell down until 1996. This happened in both sectors. In the traditional sector, the fall of the experience premium during the 1988-1996 period was much larger than the initial increase during the 1976-1988 period. In the modern sector, the magnitudes of the first increase and the subsequent decrease are more or less the same, so that the level of within-sector inequality remains similar in 1976 and 1996. Note, however, that the experience-earnings profiles here are unconditional. The cohort characteristics across experience groups possibly differ so that we need to take these differences into account to get the true experience-earnings profiles. This is done later when the simulated data from the model are compared with the actual data.

4 Estimation

4.1 Sector Partitioning

There are two types of heterogeneity in the model, (i) working sector and (ii) experience. Partitioning the workforce into modern and traditional sectors is a key measurement of the model. However, the distinction between modern and traditional sectors in the model does not have a direct counterpart in the data. The concept of being modern or traditional is a theoretical abstraction. In the literature of structural transformation, the typical partitioning characteristics are either rural versus urban as in Todaro (1969) and Lucas (2004) or agriculture versus non-agriculture as in Kuznets (1966), Hansen and Prescott (2000), and Gollin, Parente and Rogerson (2004). The “modern” sector in our partition does not necessarily correspond to urban areas or manufacturing. That is, “modernization,” measured by the transition from the traditional sector to the modern sector, can be different from the typical structural transformation such as urbanization or industrialization although they are correlated.

We attempt to construct the partitioning variable for modern and traditional sectors by combining
the disaggregated feature of the micro data with the implications of the model. Essentially, we follow a *guess-and-verify* strategy. That is, we first guess the partition using the prediction of the model on the change in employment share during transition, and then we estimate the exogenous growth rates by sectors to verify if the estimated exogenous growth rate is positive only in the modern sector as the model assumes.

To implement this strategy, we disaggregate the workforce using three-digit occupational category data combined with industry sector data, and compute the rates of change in employment shares over the two decades for each occupation category. According to the model, if an occupational category belongs to the modern sector, we expect to observe net entry to this occupation. The ranking of the occupational categories ordered by the rates of change in employment share is likely to be positively related with the likelihood of being the modern sector *in the model*. We guess a subset of occupational categories belong to the modern sector when the net entry rate is higher than some non-negative threshold level.

However, this partition is just an initial guess. The levels and changes in the populations shares of occupational categories are subject to sampling errors and there is no clear-cut threshold level of net entry rate to be applied. We are free to change the guessed partition by varying the threshold level and we need some *verifying device* to pin down the sectoral partition. Net entry to the modern sector is the *implication* of the model. The fundamental distinction between modern and traditional sectors in the model comes from the existence of the exogenous productivity growth. If the workforce is properly partitioned, we should observe positive exogenous growth of earnings over time (which is related neither to the changes in labor and experience nor to the accumulation of other productive assets and attributes) only in the modern sector, but not in the traditional sector.

We estimate the within-sector earnings functions as in the model (which are to be specified in the following subsection), to verify the existence of the presumed exogenous growth of earnings. If the estimates of the exogenous growth rates agree with the model, we take the partition in the data as representing the sector partition in the model. If not, we choose another guess and verify again. This loop of guess-and-verify is iterated until we find a right partition.

The use of disaggregated data by detailed occupational activities is helpful in identifying the sectors for two reasons. First, this helps grouping people by homogeneous skills and hence the complementarity between labor and experience is well captured using disaggregated data. Second, there
are only two sectors in the model and the model is silent on the compositional changes among the sub-groups within the modern or traditional sector. It is possible that the compositional changes among the sub-groups may offset each other if the workforce is grouped too coarsely, and we may not get informative initial guesses for the modern sector from the ranking of net entry rates.

However, there is a caveat to using disaggregated data. We may lose consistency in grouping people in terms of skills used. In the model, the sector-specific skills are defined by technology, not by occupation. It is possible that, in the data, the composition among employees, employers, and self-employed may change over time within a sector using same technology. The model is silent about this kind of compositional change. Thus, the exclusive use of net entry rates in disaggregated data may give us a wrong initial guess for the sector partition. When this kind of disaggregation problem is clear, we re-aggregate them into the same group. For example, the fastest and largest declining occupational group in Thailand is rice farmers. So, it is assigned to the traditional sector. However, the workforce share of rice-farm workers increased over time. The net-entry criterion at the initial-guess stage suggests that the rice-farm workers be assigned to the modern sector but we assign them to the traditional sector for purposes of consistency. Whether this re-arrangement is appropriate or not is verified again by observing the estimated sectoral exogenous growth rates.

Going through the above guess-and-verify process, we could partition the economy into two sectors. It turns out that on average over the sampling period, 34% of workforce belong to the modern sector and the rest, 66% to the traditional sector. The modern and traditional sectors coexist in both rural and urban areas. 47% of the urban population belongs to the traditional sector and 26% of the rural population belongs to the modern sector. Most (79%) of the urban traditional workers are trade and service workers. The rural modern workers are more or less evenly distributed across agriculture (34%), manufacturing (43%), and services (23%).

The two sectors coexist in agriculture, manufacturing, and services. The major agricultural activity in Thailand is rice farming, and most agricultural workers and farmers belong to the traditional sector. However, 15% of the agricultural workforce belong to modern sector. The modern farmers include fishery farmers (shrimp farmers), fruit farmers, and livestock farmers.

22% of manufacturing workers belong to traditional sector, including miners, metal rolling mill workers, metal casters, wood and paper product makers, chemical crushers and cookers, fiber preparers, grain millers, sugar processors and refiners, tobacco makers, tailors, blacksmith, rubber product
makers, and printing pressmen. Modern manufacturing workers include engineers, construction workers, material handling and equipment operators, electrical and electronic workers, sheet metal makers, jewelry and precious metal makers, machine tool setter-operators, mechanics, professional spinners and weavers, shoe makers, pattern makers, embroiders, potters, and food and beverage processors other than grain millers and sugar processors.

65% of service workers belong to traditional sector, including self-employed traders, street and waterway vendors, professional midwives and occupational therapists, journalists, photographers, legislative and government administrators, cooks, cleaners, hairdressers, drivers, primary school teachers, policemen, and armed forces. Modern service workers include physical and life scientists, lawyers and judges, book-keepers and accountants, communication service workers, technical salesmen, commercial artists and designers, commercial travel agencies, insurance, real estate, security service salesmen, medical doctors and nurses, pre-school and university-or-higher level teachers, and firemen.

Observing the occupational contents of the modern and traditional sectors above, we find that our partition seems to reasonably conform to our intuitive perception of being modern and traditional. It also illustrates that modern and traditional sectors may coexist even within apparently similar types of activities. For example, university-or-higher level teachers and pre-school teachers turn out to be categorized into the modern sector while primary school teachers into the traditional sector. Among protective service workers, firemen are categorized into the modern sector while policemen and armed forces into the traditional sector. Among medical service workers, doctors and nurses belong to the modern sector while professional midwives and occupational therapists to the traditional sector. Although this kind of examples are more abundant in services, they can be found also in manufacturing. For example, both blacksmith and sheet metal workers work on metal materials, but blacksmiths belong to traditional sector while sheet metal workers to modern sector. Both tailors and embroiders work in textile industry, but the former belong to traditional sector while the latter to modern sector. These examples suggests that how the workers are organizing their activities rather than what the workers are doing determines being classified as modern or traditional.
4.2 Earnings Function

As we introduced earlier, the sectoral production functions $G$ and $F$ are parameterized by the following CES forms:

$$
\text{Traditional} \quad G(L_{T,t}, E_{T,t}) = \left[ \alpha_T L_{T,t}^{\rho_T} + (1 - \alpha_T) E_{T,t}^{\rho_T} \right]^{1/\rho_T} \quad (26)
$$

$$
\text{Modern} \quad F(L_{M,t}, E_{M,t}) = \left[ \alpha_M L_{M,t}^{\rho_M} + (1 - \alpha_M) E_{M,t}^{\rho_M} \right]^{1/\rho_M} \quad (27)
$$

In a typical aggregate production function, raw labor and experience are treated as perfect substitutes, which is a special limit case of the above CES technology. Specifying the aggregate functions $G$ and $F$ for effective units of labor by the CES forms, we allow for the possibility of complementarity between labor and sector-specific experience and measure the size of the complementarity following the empirical strategy below.

From the CES specification in (26), the traditional sector earnings $\tilde{w}_{T,jt}$ of an agent with $j$ periods of experience at date $t$ is given by,

$$
\tilde{w}_{T,jt} = (\lambda_T)^j (\gamma_T)^t \left[ \alpha_T \left( \frac{L_{T,t}}{E_{T,t}} \right)^{\rho_T} + (1 - \alpha_T) \right]^{1/\rho_T - 1} \left[ \alpha \left( \frac{L_{T,t}}{E_{T,t}} \right)^{\rho_T - 1} + j(1 - \alpha_T) \right] \quad (28)
$$

where $\lambda_T$ denotes the depreciation rate and $\gamma_T$ the exogenous growth rate of productivity in the traditional sector. Note that the identifying restriction for the traditional sector from the model is $\gamma_T = 0$. As mentioned above, this is our verifying device in identifying the traditional sector. We allow $\gamma_T$ to be non-zero in our estimation. If the sector partitioning is correct, the estimated $\gamma_T$ should be close to zero.

From the CES specification in (27), the modern sector earnings $\tilde{w}_{M,jt}$ of an agent with $j$ periods of experience at date $t$ is,

$$
\tilde{w}_{M,jt} = (\lambda_M)^j (\gamma_M)^t X \left[ \alpha_M \left( \frac{L_{M,t}}{E_{M,t}} \right)^{\rho_M} + (1 - \alpha_M) \right]^{1/\rho_M - 1} \left[ \alpha_M \left( \frac{L_{M,t}}{E_{M,t}} \right)^{\rho_M - 1} + j(1 - \alpha_M) \right] \quad (29)
$$

where $\lambda_M$ denotes the depreciation rate, $\gamma_M$ the exogenous growth rate of productivity, and $X$ the time-invariant relative productivity in the modern sector. The sectoral labor and experience variables $L_{T,t}$, $E_{T,t}$, $L_{M,t}$, and $E_{M,t}$ are measured as in equations (18) to (21).

To minimize omitted-variable bias problems, we allow for exogenous variation in effective units of productivity $z_k(\chi_{k,it}, \epsilon_{k,it})$ for each sector $k \in \{T, M\}$ when applying the sectoral log-earnings
equations above to the actual data. $\chi_{k,it}$ denotes the observable productive attributes and $\epsilon_{k,it}$ the unobservable ones of an individual $i$ at date $t$. Thus, the observed earnings of individual $i$ at date $t$ in sector $k$, $w_{k,it}$ is given by,

$$w_{k,it} = z_k(\chi_{k,it}, \epsilon_{k,it})\tilde{w}_{k,j(i)t}, \text{ for } k \in \{T, M\}$$

where $j(i)$ denotes the experience of the individual $i$. We choose the typical Mincerian regressors such as years of schooling, gender, community type, and geographic region as a common set of observable characteristics $\chi_{it}$ in both sectors. We also assume $z_k(\chi_{k,it}, \epsilon_{k,it})$ to take the exponential form such that,

$$z_k(\chi_{k,it}, \epsilon_{k,it}) = \exp[A_k\chi_{k,it} + \epsilon_{k,it}]$$

where $\epsilon_{k,it}$ follows a mean-zero i.i.d normal distribution for each sector $k \in \{T, M\}$. This allows us to compare the log-earnings equations from the model with the typical Mincerian earnings regression.

In sum, we estimate the following log-earnings equations for each sector,

**Traditional**:\[ \ln w_{T,it} = j \ln \lambda_T + t \ln \gamma_T + \Psi \left( \frac{L_{T,t}}{E_{T,t}}; j; \alpha_T, \rho_T \right) + A_T \chi_{T,it} + \epsilon_{T,it} \]

**Modern**:\[ \ln w_{M,it} = j \ln \lambda_M + t \ln \gamma_M + \ln X + \Phi \left( \frac{L_{M,t}}{E_{M,t}}; j; \alpha_M, \rho_M \right) + A_M \chi_{T,it} + \epsilon_{M,it} \]

where,

$$\Psi \left( \frac{L_{T,t}}{E_{T,t}}; j; \alpha_T, \rho \right) = \left( \frac{1}{\rho_T} - 1 \right) \ln \left[ \alpha_T \left( \frac{L_{T,t}}{E_{T,t}} \right)^{\rho_T} + (1 - \alpha_T) \right] + \ln \left[ \alpha \left( \frac{L_{T,t}}{E_{T,t}} \right)^{\rho_T - 1} + j(1 - \alpha_T) \right],$$

$$\Phi \left( \frac{L_{M,t}}{E_{M,t}}; j; \alpha_M, \rho_M \right) = \left( \frac{1}{\rho_M} - 1 \right) \ln \left[ \alpha_M \left( \frac{L_{M,t}}{E_{M,t}} \right)^{\rho_M} + (1 - \alpha_M) \right] + \ln \left[ \alpha_M \left( \frac{L_{M,t}}{E_{M,t}} \right)^{\rho_M - 1} + j(1 - \alpha_M) \right].$$

$t$ denote years since the initial year 1976. So for instance, $t = 10$ for 1986.

There are two differences between the log-earnings equations in (30) and (31) and the standard Mincerian earnings equations. First, the model shows how the aggregate state variable (the sectoral labor-experience ratio $\frac{L_{k,t}}{E_{k,t}}$), as well as the individual characteristics can directly affect individual earnings. Second, the experience variable $j$ enters in a non-polynomial way and the experience premium is determined conditional on the sectoral labor-experience ratio. In other words, the sectoral labor-experience ratio determines the market value of sector-specific experience at the individual level. Note that both features directly come from the existence of complementarity. At the limit value of the complementarity parameters $\rho_T$ and $\rho_M$ at unity, the sectoral labor-experience ratio $\frac{L_{k,t}}{E_{k,t}}$ drops from the sectoral earnings equations (28) and (29).
4.3 Identification

All the technology parameters \( \{\alpha_T, \rho_T, \alpha_M, \rho_M, \gamma_M, \gamma_T, \lambda_M, \lambda_T, X\} \) are included in the log-earnings equations (30) and (31). Thus, we can estimate the technology parameters from these sectoral log-earnings equations without using aggregate dynamics data such as output growth and population transition. These aggregate dynamics are to be simulated at the parameters estimated from the individual log-earnings equations.

This estimation strategy has two kinds of merit. First, due to the standard endogeneity bias problem, the technology parameters cannot be identified from the aggregate time series relationship directly using the production functions in (26) and (27). Furthermore, there are no national income statistics or aggregate time series data to be matched to calibrate the complementarity between labor and experience. Estimating the parameters from the individual earnings equations faces neither problem. Using the structural equations (30) and (31) explicitly derived from the model, the fundamental parameters can be estimated consistently with the economic environment of the model. From the estimates and their standard errors, explicit estimation helps us to infer the relevant range of parameter space, where the model is applicable in explaining a specific real economy.

Second, by not using the aggregate dynamics data in the parameter selection step, the over-fitting problem can be avoided when we compare the aggregate dynamics of output growth and sectoral transition between the model and the data. Thus, we follow the main spirit of calibration: separation between parameter selection and model evaluation.

Now the issue of identification remains for the log-earnings equations (30) and (31). In the traditional log-earnings equation (30), the terms \( j \ln \lambda_T \) and \( t \ln \gamma_T \) are additively separable and can be identified. The remaining parameters \( \alpha_T \) and \( \rho_T \) are to be identified from the two non-linear terms,

\[
\Psi \left( \frac{L_{T,t}}{E_{T,t}}, j; \alpha_T, \rho_T \right) \equiv \left( \frac{1}{\rho_T} - 1 \right) \ln \left[ \alpha_T \left( \frac{L_{T,t}}{E_{T,t}} \right)^{\rho_T} + (1 - \alpha_T) \right] + \ln \left[ \alpha_T \left( \frac{L_{T,t}}{E_{T,t}} \right)^{\rho_T-1} + j(1 - \alpha_T) \right]
\]

Note that the experience-earnings profile is time-invariant, and hence \( (1 - \alpha_T) \) can be identified from the cross-sectional variation of experience through the term second term above (at a given date \( t \), the first term is constant). Given \( \alpha_T \), the complementarity parameter \( \rho_T \) can be identified from the time-series variation of \( \frac{L_{T,t}}{E_{T,t}} \) from the pooled data over time. The same identification strategy applies to the modern sector. Therefore, all the technology parameters can be identified except \( X \). Given that there are dummy variables in \( A_M \chi_{T,t} \), the estimated constant includes both \( X \) and the average
income of the reference group in the modern sector. The same is true for the traditional sector. Thus, a simple comparison between the estimated sectoral constant terms does not identify \( X \). We outline the procedure for calibrating \( X \), in the simulation section below.

4.4 Estimates

We use the nonlinear-least-squares method to estimate the sectoral log-earnings equations in (30) and (31). The estimates are reported in [Table 1] and [Table 2], respectively for traditional and modern sectors, with standard errors in parentheses. The goodness-of-fit in terms of \( R^2 \), 0.3928 for the modern sector and 0.2852 for the traditional sector, seems fairly high relative to the typical earnings regressions. We can confirm that the estimated exogenous growth rate of productivity of the traditional sector \( \gamma_T \) is indeed close to zero while that of modern sector \( \gamma_M \) is substantially higher than zero at 2.3% per annum. The depreciation factors \( \lambda_T \) and \( \lambda_M \) are quite similar between the traditional and modern sectors.

The estimates of \( \rho_T \) and \( \rho_M \) suggest that the complementarity is strong. In both sectors, labor and experience are far from perfect substitutes, and the elasticity of substitution is even lower than in the Cobb-Douglas case. In particular, the complementarity is much higher in the traditional sector at -13.19 than in the modern sector at -0.05. The pure experience premium parameter \( (1 - \alpha_T) \) is also higher in the traditional sector than \( (1 - \alpha_M) \) in the modern sector. Thus, experience seems more valuable in the traditional sector than in the modern sector. However, note that the market reward to individual experience depends on aggregate state variables, sectoral labor-experience ratios, which vary over time due to exogenous productivity growth in the modern sector. As more people move to the modern sector, the experience premium in the traditional sector is eventually supposed to decline.

The estimates for the coefficients of the control variables provide us with further interesting information. These coefficients can be interpreted as the “prices” of the productive attributes such as higher schooling, being male, or living in better endowed regions. The rates of return to schooling seem fairly high in both sectors, 12.8 percent for the modern sector and 14.3 percent for the traditional sector. Another interesting observation is that, except for the coefficient for the male dummy, the prices are uniformly higher in the traditional sector than in the modern sector for all characteristics.

<p>| Table 1. Estimates for Technology Parameters | 25 |</p>
<table>
<thead>
<tr>
<th>Sector</th>
<th>$\alpha_M, \alpha_T$</th>
<th>$\rho_M, \rho_T$</th>
<th>$\gamma_M, \gamma_T$</th>
<th>$\lambda_M, \lambda_T$</th>
<th>$R^2$</th>
<th>$RMSE$</th>
<th>#Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern</td>
<td>0.2293 (0.0921)</td>
<td>-0.0511 (0.3256)</td>
<td>0.0240 (0.00071)</td>
<td>0.9282 (0.0012)</td>
<td>0.3928</td>
<td>0.9053</td>
<td>64,812</td>
</tr>
<tr>
<td>Traditional</td>
<td>1.14e-12 (1.25e-12)</td>
<td>-13.1893 (0.5183)</td>
<td>-0.0048 (0.0005)</td>
<td>0.932259 (0.0012)</td>
<td>0.2852</td>
<td>0.9598</td>
<td>100,785</td>
</tr>
</tbody>
</table>

Table 2. Estimates for Control Variables

<table>
<thead>
<tr>
<th>Sector</th>
<th>Schooling</th>
<th>Male</th>
<th>Urban</th>
<th>North</th>
<th>Central</th>
<th>South</th>
<th>Bangkok</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern</td>
<td>0.1264 (0.0010)</td>
<td>0.3912 (0.0076)</td>
<td>0.3089 (0.0097)</td>
<td>0.0324 (0.0137)</td>
<td>0.3286 (0.0125)</td>
<td>0.2547 (0.0129)</td>
<td>0.6034 (0.0132)</td>
</tr>
<tr>
<td>Traditional</td>
<td>0.1396 (0.0012)</td>
<td>0.3847 (0.0066)</td>
<td>0.5258 (0.0108)</td>
<td>0.0899 (0.008)</td>
<td>0.4038 (0.0087)</td>
<td>0.2974 (0.0112)</td>
<td>0.7299 (0.0128)</td>
</tr>
</tbody>
</table>

5 Simulation

Using the generalized $s$-period overlapping generations model, we take $s = 20$ in simulation and each period in the model corresponds to 3 years in the data. We set calendar year 1976 as $t = 0$ in the model. From the estimation, we take seven parameters of the model $\{\alpha_T, \alpha_T, \rho_T, \rho_M, \lambda_T, \lambda_M, \gamma_M\}$, and set $\gamma_T = 0$. We take $\beta = \frac{1}{R}$, where $R$ is calibrated to match the average Thai real interest rate data, measured by the inflation-adjusted Thai commercial bank lending rate, during the sample period. [Figure 9] shows that over the sample period, the Thai real interest rate has fluctuated between -0.03 and 0.16 with an average of 0.08. Thus, the implied three-year discount factor $\beta = \left(\frac{1}{0.08}\right)^3 = 0.79$.

The initial state of the Thai economy in 1976 is the set of modern sector cohort shares over three-year intervals dating back to cohort who entered in calendar year 1919, $\{N_{-i}\}_{i=1}^{19}$, as measured in the data is reported in Table 3,

Table 3. Initial State of Thai economy

<table>
<thead>
<tr>
<th>$N_{-19}$</th>
<th>$N_{-18}$</th>
<th>$N_{-17}$</th>
<th>$N_{-16}$</th>
<th>$N_{-15}$</th>
<th>$N_{-14}$</th>
<th>$N_{-13}$</th>
<th>$N_{-12}$</th>
<th>$N_{-11}$</th>
<th>$N_{-10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.183</td>
<td>0.189</td>
<td>0.195</td>
<td>0.201</td>
<td>0.205</td>
<td>0.209</td>
<td>0.213</td>
<td>0.218</td>
<td>0.223</td>
<td>0.229</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$N_{-9}$</th>
<th>$N_{-8}$</th>
<th>$N_{-7}$</th>
<th>$N_{-6}$</th>
<th>$N_{-5}$</th>
<th>$N_{-4}$</th>
<th>$N_{-3}$</th>
<th>$N_{-2}$</th>
<th>$N_{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.240</td>
<td>0.246</td>
<td>0.257</td>
<td>0.270</td>
<td>0.286</td>
<td>0.305</td>
<td>0.327</td>
<td>0.352</td>
<td>0.380</td>
</tr>
</tbody>
</table>

[Figure 10] shows that the distribution of experience groups in the labor force is not uniform in the Thai economy. It is rather hump-shaped. We exogenously embed this demographic structure of the labor market into the model in computing simulated labor and experience.

There remains one more free parameter, the relative productivity gap in 1976, $X$. This is chosen at $X = 1.047$ to match the modern cohort share in the initial year 1976 between the model and the data $N_0 = 0.411$.  

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5.1 Simulation Results

Given the calibrated $X$, initial distribution and the estimated parameters, the result of the simulation is the list $\{N_{it}^{\ast}\}_{i=0}^{t^\ast}$: the simulated cohort shares and the first period of full cohort entry into the modern sector $t^\ast$. The simulated earnings, constructed using these results, are compared with data after we filter out the estimated effect of the control variables \{schooling, gender, community type, geographic region\} from the actual earnings. Specifically, our filtered earnings are measured by,

$$
Traditional: \ln w_{T, it}^{Filter} = \ln w_{T, it} - \tilde{A}_T X_{T, it} = j \ln \lambda_T + t \ln \gamma_T + \Psi \left( \frac{L_T, t}{E_T, t}; \alpha_T, \rho_T \right) + \epsilon_{T, it} \tag{32}
$$

$$
Modern: \ln w_{M, it}^{Filter} = \ln w_{M, it} - \tilde{A}_M X_{M, it} = j \ln \lambda_M + t \ln \gamma_M + \ln X + \Phi \left( \frac{L_M, t}{E_M, t}; \alpha_M, \rho_M \right) + \epsilon_{M, it} \tag{33}
$$

where $\tilde{A}_T$ is the estimate from the traditional earnings equation, and $\tilde{A}_M$ is the estimate from the modern earnings equation except the constant term. We subtract the constant term of the traditional sector from the modern sector as well to reproduce the sectoral earnings gap as is estimated from the data. As discussed above, this earnings gap reflects both the relative efficiency gap $X$ and the difference in income levels of of the reference groups between sectors. We refer to such data as "filtered data".

1. Average labor earnings dynamics. The filtered earnings data displays a fall during the first decade of the sample period, followed by an increase [Figure 11]. This differs dramatically with the raw data in [Figure 3] which displays a stagnation then take-off of earnings around 1986. The model predicts well the level of earnings at the beginning and end period, but not the fluctuation in between. The model is not supposed to capture this kind of business cycle fluctuation, and we interpret this as an outcome of factors outside the model.

[Figure 12] compares the simulated path of average earnings in the modern and traditional sectors versus overall average earnings for 1976-2036. Note that average earnings are initially lower in the modern sector. As the economy undergoes transition from the traditional to modern sector, the overall earnings displays an S-shaped path. [Figure 12] also shows the path of overall average earnings in a hypothetical economy where everyone is working in the modern sector which we label "full transition" economy. Note overall earnings are initially higher than the full transition economy, and eventually converges to that of the full transition economy.

The average earnings in the full transition economy can be lower than that in the transition economy due to the compositional effect at a given date. This does not imply welfare is lower in the
full transition economy. The correct measure of welfare in the context of the model is lifetime earnings. [Figure 13] compares lifetime earnings in the simulated Thai economy versus that for the full transition economy for 1976-2036. Lifetime incomes in the simulation and full transition economy are not very different. Qualitatively, when we refer back to the comparative statics section, the parameters for the Thai economy imply the model is closer to Experiment 2 [Figure 2] than Experiment 1 [Figure 1].

2. Transition of the labor force. The model simulates cohort entry into the modern sector from 1976 onwards. Recall $X$ is chosen to match $N_0$ in the data. After an initial overshooting in 1979, the model captures the trend of the transition quite well in [Figure 14]. The first period at which the entire cohort is predicted to enter the modern sector is $t^* = 12$, which corresponds to 2012 in calendar years. [Figure 15] shows how the aggregate labor share of the modern sector displays an S-shaped transition over 1976-2036. Since the model overpredicts entry into the modern sector, the simulated labor share is higher than in the data, but the gap does not seem large. Overall, the model predicts well the gradual increase in the modern share of workers. By 2036, the model predicts that about 90% of the workforce produce in the modern sector.

3. Inter-sectoral earnings inequality. [Figure 16] compares the simulated ratio of modern average earnings over traditional average earnings with the filtered data for 1976-2036. In simulation, the average earnings of the traditional sector is higher than the modern sector. The simulated ratio starts from 0.6 in 1976 and gradually increases and exceeds 1 by 2006, thereafter accelerating to 3 by 2036. The filtered data displays significantly less inter-sectoral earnings inequality of about 1.2 than in the raw data of about 1.6. Given our inability of identifying $X$ in the data, the level comparison of sectoral earnings inequality does not deliver much information. However, the model captures well the observed upward trend in inter-sectoral inequality during the sample period.

4. Intra-sectoral earnings inequality. [Figure 17] shows the evolution of labor to experience ratios in the simulation and data for each sector for 1976-2036. The simulation predicts well the evolution of labor-experience ratios in each sector. Remarkably, in the modern sector, the simulation correctly matches the single peak of the labor-experience ratio around 1986 observed in the data. In the traditional sector, the labor-experience ratio is weakly, but monotonically falling in the simulation, while in the data there is a moderate upturn initially, and then a gradual fall.

The labor-experience ratio determines the experience-earnings profile. From [Figure 18] and [Figure 19] we compare the modern experience-earnings profiles for each year between the model and
the filtered-data. From [Figure 20] and [Figure 21] we compare the traditional experience-earnings profiles for each year between the model and the filtered-data. The zero-experience wage is normalized to 1.

When comparing [Figure 19] with [Figure 7] and [Figure 21] with [Figure 8], a remarkable observation is how in both sectors, the experience premium gets magnified in the filtered data. Much of this comes from the fact that younger cohorts acquire more schooling than older cohorts. In the modern sector simulation, the experience-earnings profile shifts up between 1976 and 1990, then shifts down slightly by 1996. In the modern sector data, shifts in the experience-earnings profile seem noisier.

The simulated fall in the experience premium between 1976 to 1996, is pronounced in the traditional sector. The simulation correctly predicts a fall in the experience premium as in the filtered data, although the simulation overpredicts this fall. Overall, the simulation matches well the change of the experience premium in each sector, and the magnitude in the case of the traditional sector. The implied intra-sectoral inequality shows an inverted-U shape, as Kuznets (1955) postulated.

Experience premiums in the filtered data of the order of 4-7 in both sectors are notably much higher than the usual experience premiums measured for the U.S. of the order of 1.5 to 3, as documented by Mincer (1958) and Katz and Murphy (1992) among others. In the context of our model, this is a feature of an economy undergoing transition. The model predicts that during transition labor-experience ratios are higher in both sectors compared to outcomes when transition is complete, i.e. a full transition economy. Consequently, experience premia are lower in economies once modern transition is complete. In particular, when we substitute in the implied labor experience ratio under full transition, the experience premia fall to the order of 1.5 to 3, the range of U.S. estimates. For the modern sector, the theory paints a more subtle story during transition in that experience premia are predicted to rise then fall, since the evolution of labor-experience ratios are single peaked.

6 Conclusion

This paper has shown that a model of transition from traditional to modern sector production can jointly provide (i) a useful theory of why industrialization occurs at different times and at different rates, and (ii) how income inequality within countries evolves during the course of industrialization. The model provides a micro foundation of the growth-inequality nexus for transitional economies without relying on any policy and institutional distortions.
Using the model and the rich micro data from Thailand, we could identify the dual-economy partition and measure the sector-specific complementarity as well as most of the deep parameters of the model. We found that at the estimated parameters, and initial state of distribution of experience across sectors, the model captures (i) the take-off of the aggregate earnings and the S-shaped transition, (ii) the speed of sectoral transition in the workforce, (iii) the overall increasing trend in the inter-sectoral earnings inequality, and (iv) the changes in experience-earnings profiles, in particular the large drop in experience premium in the traditional sector observed in Thai data between 1976 and 1996.

When comparing the simulation to data, the speed of transition seems faster, and the S-shaped curvature of lifetime earnings seems rather weak. This may indicate that the model is missing some key features of transitional growth leaving room for some forms of policy distortions. How the growth of earnings can be reconciled with the growth of Thai per capita incomes is a related remaining issue. Earnings and per capita income differ because of physical capital. The longer-run pattern of GDP per capita from Maddison (2001) seems different from the earnings growth pattern during our sample period. If the physical capital share of output is higher in the modern sector, the model predicts that during transition, per capita income growth is faster than per capita earnings growth. In fact, Jeong and Townsend (2005) show that the observed accelerated growth in Thai GDP per capita after 1986 can be explained by the financial deepening in Thailand. This hypothesis is worth exploring further.

The current model assumes experience cannot be transferred across generations within family dynasties. Since earnings profiles are typically steeper in the modern sector, the longer time horizon in making sectoral entry decisions would slow down the transition toward the modern sector. Currently, the model overpredicts the speed of transition toward the modern sector.

The model suggests that the relevant variable regarding experience in explaining income differences is the distribution of experience across sectors. We found that the estimated size of the complementarity is quite large, in particular for the traditional sector. This suggests that using aggregate experience as measuring human capital in development accounting may be quite misleading. Incorporating the distribution of experience across sectors, the size of the TFP differences will be reduced. Applying the model to the cross-country development accounting exercise as well as to growth accounting for other countries are agendas for future research.
References


A Proofs

Proof of Lemma 1. Suppose not so, \( N_{t-1} = 1 \) and \( N_t < 1 \). From (9), \( N_{t-1} = 1 \) implies,

\[
g'(1) + \beta \lambda \left[ g'(1) + \phi(1) \right] \\
\leq \gamma^{t-1} X \left\{ f' \left( 1 + \frac{1}{\lambda N_{t-2}} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{N_t}{\lambda} \right) + \pi \left( 1 + \frac{N_t}{\lambda} \right) \right] \right\}
\]

\( N_t < 1 \) implies,

\[
\nu_T + \beta \lambda \left[ g' \left( 1 + \frac{1}{\lambda (1 - N_t)} \right) + \phi \left( 1 + \frac{1}{\lambda (1 - N_t)} \right) \right] \\
= \gamma^t X \left\{ f' \left( 1 + \frac{N_t}{\lambda} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{N_{t+1}}{\lambda N_t} \right) + \pi \left( 1 + \frac{N_{t+1}}{\lambda N_t} \right) \right] \right\}
\]

which implies \( N_{t+1} < N_t \) and so on until we get \( N_j = 0 \),

\[
g' \left( 1 + \frac{1}{\lambda (1 - N_{j-1})} \right) + \beta \lambda \left[ g' \left( 1 + \frac{1}{\lambda} \right) + \phi \left( 1 + \frac{1}{\lambda} \right) \right] \\
\geq \gamma^j X \left\{ f'(1) + \beta \lambda \gamma \left[ f'(1) + \pi(1) \right] \right\}
\]

Which contradicts Condition A when noting that,

\[
f' \left( 1 + \frac{1}{\lambda} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{1}{\lambda} \right) + \pi \left( 1 + \frac{1}{\lambda} \right) \right] \\
> f'(1) + \beta \lambda \gamma \left[ f'(1) + \pi(1) \right]
\]

Since \( f'(x) + \beta \lambda \gamma \left[ f'(x) + \pi(x) \right] \) is falling in \( x \) for \( x < 1 + \frac{1}{\lambda} \). ■

Proof of Proposition 1. The algorithm for constructing the equilibrium transition path is as follows:

Step 1: Given \( N_{-1} \), guess that \( N_t = 1 \) for \( \forall t \geq 0 \). Verify if \( N_0 = 1 \) by checking (11) for \( T = 1 \). If the inequality holds \( T = 1 \). If the inequality doesn’t hold, \( T > 1 \) go to step 2.

Step 2: Given \( N_{-1} \), determine \( N_0 \) guessing \( N_t = 1 \) for \( \forall t \geq 1 \),

\[
g' \left( 1 + \frac{1 - N_0}{\lambda (1 - N_{-1})} \right) + \beta \lambda \left[ g'(1) + \phi(1) \right] = X \left\{ f' \left( 1 + \frac{N_0}{\lambda N_{-1}} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{1}{\lambda N_0} \right) + \pi \left( 1 + \frac{1}{\lambda N_0} \right) \right] \right\}
\]

Since \( \frac{1}{N_0} > 1 \), from (7) we must have \( \frac{N_0}{N_{-1}} > 1 \Rightarrow \frac{1 - N_0}{1 - N_{-1}} < 1 \). The left hand side of this equation is rising in \( N_0 \), and the right hand side is falling in \( N_0 \). Given \( T > 1 \), there exists a unique \( N_0 \in (0, 1) \) which solves this equality. Verify if \( N_1 = 1 \) by checking (11) for \( T = 2 \). If the inequality holds, \( T = 2 \). If the inequality doesn’t hold \( T > 2 \) go to step 3.

Step 3: Given \( N_{-1} \), determine \( N_0, N_1 \) guessing \( N_t = 1 \) for \( \forall t \geq 2 \),

\[
g' \left( 1 + \frac{1 - N_0}{\lambda (1 - N_{-1})} \right) + \beta \lambda \left[ g' \left( 1 + \frac{1 - N_1}{\lambda (1 - N_0)} \right) + \phi \left( 1 + \frac{1 - N_1}{\lambda (1 - N_0)} \right) \right] \\
= X \left\{ f' \left( 1 + \frac{N_0}{\lambda N_{-1}} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{N_1}{\lambda N_0} \right) + \pi \left( 1 + \frac{N_1}{\lambda N_0} \right) \right] \right\}
\]

\[
g' \left( 1 + \frac{1 - N_1}{\lambda (1 - N_0)} \right) + \beta \lambda \left[ g'(1) + \phi(1) \right] \\
= X \gamma \left\{ f' \left( 1 + \frac{N_1}{\lambda N_0} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{1}{\lambda N_1} \right) + \pi \left( 1 + \frac{1}{\lambda N_1} \right) \right] \right\}
\]
Since $\frac{1}{N_0} > 1$, from (7) we must have $\frac{N_2}{N_0} > 1 \Rightarrow \frac{N_2}{N_0} > 1$ using (11) again. In the first equation, given $N_1 \in (0, 1)$, there exists a unique $N_0 \in (0, 1)$ which solves the equality. In the second equation, given $N_0 \in (0, 1)$, there exists a unique $N_1 \in (0, 1)$ solving the equation. Verify if $N_2 = 1$ by checking (11) for $T = 3$. If the inequality holds $T = 3$, if the inequality doesn’t hold $T > 3$ go to step 4, and so on.

This procedure identifies an equilibrium with the lowest $T$. Next we show given such an equilibrium there cannot exist another equilibrium with higher $T' > T$. Suppose not so, given an equilibrium $\{N_0, \ldots, N_{T-1}, T\}$ there exists another equilibrium $\{N'_0, \ldots, N'_{T-1}, T'\}$ where $T' > T$. Then $\frac{1}{N'_T} > 1 \Rightarrow \frac{N'_T}{N'_{T-1}} > 1$ and $\frac{N'_T}{N'_{T-2}} > \frac{N'_{T-1}}{N'_{T-2}}$ by induction using the participation constraints. Using the participation constraints repeatedly this implies, $\frac{N'_T}{N'_{T-1}} > \frac{N'_0}{N_{T-1}}$. We know from the condition for $T$ of the original equilibrium, $N'_T < N_T \Rightarrow N'_T < N_T - 2$ and so on until $N'_0 < N_0$ which is a contradiction.

To complete the proof for uniqueness an equilibrium $\{N_0, \ldots, N_{T-1}\}$ must be unique given $T$. Suppose not so that there exists a $N'_t \neq N_t$ for some $t \in \{0, \ldots, T - 1\}$. The participation constraints imply that $N'_{T-1} \neq N_{T-1}$, so we just need to show that $N'_{T-1} \neq N_{T-1}$ leads to contradiction. Suppose $N'_{T-1} > N_{T-1}$, then to ensure the participation constraints hold, $\frac{N'_t}{N_{T-1}} < \frac{N'_0}{N_{T-1}} \Rightarrow N'_0 < N_0$ given $N_{T-1} \Rightarrow N'_0 < N_t$ and $N'_t = N_{T-1} < N_{T-1}$ which is a contradiction. Suppose $N'_{T-1} < N_T$, now to ensure the participation constraints hold, $\frac{N'_t}{N_{T-1}} > \frac{N'_0}{N_{T-1}} \Rightarrow N'_0 > N_0$ given $N_{T-1} \Rightarrow N'_0 < N_t$ and $N'_{T-1} > N_{T-1}$ which is a contradiction.

Parts (iii) and (iv) are straightforward from participation constraints and condition (11) for $T$. □

**Proof of Proposition 2.** (i) Increasing lifetime income increasing implies,

$$
g'(1 + \frac{1 - N_1}{\lambda(1 - N_0)}) + \beta \lambda [g'(1 + \frac{1 - N_1}{\lambda(1 - N_0)}) + \phi (1 + \frac{1 - N_2}{\lambda(1 - N_1)})] \leq ... \leq g'(1 + \frac{1 - N_{T-1}}{\lambda(1 - N_{T-2})}) + \beta \lambda [g'(1 + \frac{1 - N_{T-1}}{\lambda(1 - N_{T-2})}) + \phi (1 + \frac{1 - N_{T-1}}{\lambda(1 - N_{T-2})})] \leq g'(1 + \frac{1 - N_{T-1}}{\lambda(1 - N_{T-2})}) + \beta \lambda [g'(1) + \phi (1)]$$

$\frac{1 - N_{T-1}}{\lambda(1 - N_{T-2})} > 0 \Rightarrow \frac{1 - N_{T-2}}{\lambda(1 - N_{T-3})} > \frac{1 - N_{T-1}}{\lambda(1 - N_{T-2})}$ since $g'(\cdot)$ is decreasing and $\phi(\cdot)$ is increasing, and so on by iteration. (ii) Define $S$ such that, for $t < S$, lifetime income is growing slower than $\gamma$,

$$f'(1 + \frac{N_{t-1}}{\lambda N_{t-2}}) + \beta \lambda \gamma [f'(1 + \frac{N_t}{\lambda N_{t-1}}) + \pi (1 + \frac{N_t}{\lambda N_{t-1}})] > f'(1 + \frac{N_{t-1}}{\lambda N_{t-2}}) + \beta \lambda \gamma [f'(1 + \frac{N_t}{\lambda N_{t-1}}) + \pi (1 + \frac{N_t}{\lambda N_{t-1}})]$$

and for $t \geq S$, lifetime income is growing faster than $\gamma$,

$$f'(1 + \frac{N_{t-1}}{\lambda N_{t-2}}) + \beta \lambda \gamma [f'(1 + \frac{N_t}{\lambda N_{t-1}}) + \pi (1 + \frac{N_t}{\lambda N_{t-1}})] \leq f'(1 + \frac{N_{t-1}}{\lambda N_{t-2}}) + \beta \lambda \gamma [f'(1 + \frac{N_t}{\lambda N_{t-1}}) + \pi (1 + \frac{N_t}{\lambda N_{t-1}})]$$

For $t \geq S$, $\frac{N_{t+1}}{N_t} < \frac{N_t}{N_{t-1}}$ by an argument resembling that used in part (i). Thus, $Q < S$. 34
The proof for \( t < S \) is in two parts. By construction \( \frac{N_Q}{N_{Q-1}} \geq \frac{N_{Q+1}}{N_Q} \). During transition, for \( t < S \),

\[
\frac{f'}{f'} \left( 1 + \frac{N_Q}{\lambda N_{Q-1}} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{N_{Q+1}}{\lambda N_Q} \right) + \pi \left( 1 + \frac{N_{Q+1}}{\lambda N_Q} \right) \right] \\
> \frac{f'}{f'} \left( 1 + \frac{N_{Q-2}}{\lambda N_{Q-3}} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{N_{Q-1}}{\lambda N_{Q-2}} \right) + \pi \left( 1 + \frac{N_{Q-1}}{\lambda N_{Q-2}} \right) \right]
\]

Which then implies \( \frac{N_{Q+1}}{N_Q} > \frac{N_Q}{N_{Q-1}} \), and so on by induction.

By construction \( \frac{N_{Q+1}}{N_Q} < \frac{N_Q}{N_{Q-1}} \). During transition, for \( t < S \),

\[
\frac{f'}{f'} \left( 1 + \frac{N_{Q-2}}{\lambda N_{Q-3}} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{N_{Q-1}}{\lambda N_{Q-2}} \right) + \pi \left( 1 + \frac{N_{Q-1}}{\lambda N_{Q-2}} \right) \right] \\
> \frac{f'}{f'} \left( 1 + \frac{N_{Q-2}}{\lambda N_{Q-3}} \right) + \beta \lambda \gamma \left[ f' \left( 1 + \frac{N_{Q-1}}{\lambda N_{Q-2}} \right) + \pi \left( 1 + \frac{N_{Q-1}}{\lambda N_{Q-2}} \right) \right]
\]

Which then implies \( \frac{N_{Q-2}}{N_{Q-3}} < \frac{N_{Q-1}}{N_{Q-2}} \), from the equation above and so on by induction.

In period \( T-1 \), lifetime income is \( X \gamma^{T-1} \left[ f' \left( 1 + \frac{1}{\lambda N_{T-2}} \right) + \beta \lambda \gamma \left[ f' \left( \frac{1+\lambda}{\lambda} \right) + \pi \left( \frac{1+\lambda}{\lambda} \right) \right] \right] \). In period \( T \), lifetime income is \( X \gamma^{T} \left[ f' \left( \frac{1+\lambda}{\lambda} \right) + \beta \lambda \gamma \left[ f' \left( \frac{1+\lambda}{\lambda} \right) + \pi \left( \frac{1+\lambda}{\lambda} \right) \right] \right] \). So between period \( T-1 \) and \( T \), lifetime income is growing faster than \( \gamma \), and after period \( T \), it grows at rate \( \gamma \). Thus, \( Q < S \leq T - 1 \).

There are three possibilities for the path of \( \frac{N_{i+1}}{N_i} \): (i) it is rising until \( t = T - 1 \) and \( Q = T - 1 \), (ii) it is falling and \( Q = 1 \), and (iii) it is rising and then falling. Thus, the population growth of the modern sector is single peaked.

## B Equilibrium for S-period Model

A competitive equilibrium consists of a sequence of sectoral entry decisions \( \{N_i\}_{t=0}^{\infty}, \{M_i\}_{t=0}^{\infty} \), such that in every period \( t \),

(i) every agent earns wages equal to his marginal product,
(ii) new born agents choose which sector to work in for the rest of their lives, and how much to consume each period to maximize their lifetime utility (16) given the interest factor \( R \),

wages implied by (3), the distribution of labor across sectors in period \( t \),

\( \{N_{t-i}\}_{i=1}^{s-1}, \{M_{t-i}\}_{i=1}^{s-1} \), the distribution of labor across sectors in periods \( t+j \),

\( \{N_{t+j-i}\}_{i=1}^{s-1}, \{M_{t+j-i}\}_{i=1}^{s-1} \) \( j \in \{1,...,s-1\} \), and budget constraint (17),

(iii) the resource constraints (18)-(22) are satisfied.

In equilibrium, ex ante identical young agents in period \( t \) choose with sector to work in for the rest of their lives according to,

\[
\max \left\{ \sum_{j=0}^{s-1} (\beta \lambda)^j \left[ g' \left( \frac{L_{T,t+j}}{E_{T,t+j}} \right) + j \phi \left( \frac{L_{M,t+j}}{E_{M,t+j}} \right) \right], \gamma^t X \sum_{j=0}^{s-1} (\beta \lambda)^j \gamma^j \left[ f' \left( \frac{L_{M,t+j}}{E_{M,t+j}} \right) + j \pi \left( \frac{L_{M,t+j}}{E_{M,t+j}} \right) \right] \right\}
\]

(34)

If young agents enter both sectors in period \( t \), \( N_t \in (0,1) \). Using the resource constraints and the
definitions of labor and experience from (18)-(22),
\[
\sum_{j=0}^{s-1} (\beta \lambda)^j \left[ g' \left( \frac{1-\lambda^s}{1-\lambda} - \sum_{i=0}^{s-1} \lambda^i N_{t+j-i} \right) + j \phi \left( \frac{1-\lambda^s}{1-\lambda} - \sum_{i=0}^{s-1} i \lambda^i N_{t+j-i} \right) \right] = \gamma^t X \sum_{j=0}^{s-1} (\beta \lambda)^j \gamma^j \left[ f' \left( \sum_{i=0}^{s-1} \lambda^i N_{t+j-i} \right) + j \pi \left( \sum_{i=0}^{s-1} i \lambda^i N_{t+j-i} \right) \right]
\]

Lemma A1 Let T denote the first period at which the entire population is working in the modern sector. Given \( N_{t-(s-1)} = 1 \) through to \( N_{t-1} = 1 \), then \( N_{t+j} = 1 \ \forall j \geq 0 \), and \( t = T \).

Proof. From (34), \( N_{t-(s-1)} = 1 \) through to \( N_{t-1} = 1 \) implies,
\[
g' \left( \frac{1}{s-1} \right) + \sum_{j=1}^{s-1} (\beta \lambda)^j \left[ g' \left( \frac{1}{j} \right) + j \phi \left( \frac{1}{j} \right) \right] \leq \gamma^{t-1} X \sum_{j=1}^{s-1} (\beta \lambda)^j \gamma^j \left[ f' \left( l^* \right) + j \pi \left( l^* \right) \right]
\]
Since \( g'' (\cdot) < 0, f'' (\cdot) < 0 \), and \( N_{t-s} < 1 \Rightarrow \frac{1-\lambda^s + \lambda^{s-1} (N_{t-s} - 1)}{1-\lambda - (s-1) \lambda^{s-1} (N_{t-s} - 1)} > l^* \), this condition implies the condition for \( N_t = 1 \),
\[
\sum_{j=0}^{s-1} (\beta \lambda)^j \left[ g' \left( \frac{1}{j} \right) + j \phi \left( \frac{1}{j} \right) \right] \leq \gamma^t X \sum_{j=0}^{s-1} (\beta \lambda)^j \gamma^j \left[ f' \left( l^* \right) + j \pi \left( l^* \right) \right]
\]
The left hand side denotes the lifetime product of an agent working alone in the traditional sector. In this case, the traditional sector labor experience ratio is simply given by \( \frac{1}{j} \). Note \( g' (\infty) \) denotes the marginal product of labor in the absence of experience.
Since \( \gamma > 1 \), if this condition is satisfied for \( N_t = 1 \), it must be satisfied for \( N_{t+j} = 1 \ \forall j \geq 1 \).

If young agents enter the modern sector only in period \( t \), \( N_t = 1 \),
\[
\sum_{j=0}^{s-1} (\beta \lambda)^j \left[ g' \left( \frac{1-\lambda^s}{1-\lambda} - \sum_{i=0}^{s-1} \lambda^i N_{t+j-i} \right) + j \phi \left( \frac{1-\lambda^s}{1-\lambda} - \sum_{i=0}^{s-1} i \lambda^i N_{t+j-i} \right) \right] \leq \gamma^t X \sum_{j=0}^{s-1} (\beta \lambda)^j \gamma^j \left[ f' \left( \sum_{i=0}^{s-1} \lambda^i N_{t+j-i} \right) + j \pi \left( \sum_{i=0}^{s-1} i \lambda^i N_{t+j-i} \right) \right]
\]
In the \( s = 2 \) model there was a single terminal vintage condition. In the general model, there are \((s-1)\) terminal vintage conditions. (35) and (36) characterize a system of differential equations in \( N_t \) of order \((s-1)\).

**Proposition A1: Equilibrium construction**
Since \( \gamma > 1 \), and the lifetime product of agents working in the traditional sector is always finite, there exists a finite terminal period \( T < \infty \) for which transition is complete. That is, there exists a \( T < \infty \) for which the inequality (36) holds for \( N_{T-(s-1)} = 1 \) through to \( N_{T-1} = 1 \).
The algorithm for constructing the equilibrium transition path is as follows:

**Step 1:** If $N_{-1} < 1$, $T \geq s - 1$. $T = s - 1$ occurs if $N_t = 1 \ \forall t \geq 0$. Given $\{N_{-i}\}_{i=1}^{s-1}$, guess that $N_t = 1 \ \forall t \geq 0$.

Verify this by checking whether inequality (36) holds for $N_0 = 1$ through to $N_{s-2} = 1$. If these inequalities hold $T = s - 1$. If they do not all hold, $T > s - 1$ go to step 2.

**Step 2:** Given $\{N_{-i}\}_{i=1}^{s-1}$, guess that $N_t = 1 \ \forall t \geq 1$. Then determine $N_0 \in (0, 1)$ using participation constraint (35). The left hand side of this participation constraint is rising in $N_0$, and the right hand side is falling in $N_0$. Given $T > s - 1$, there exists a unique $N_0 \in (0, 1)$ which solves this equality.

Verify if $N_t = 1 \ \forall t \geq 1$ by checking whether inequality (36) holds for $N_1 = 1$ through to $N_{s-1} = 1$. If these inequalities hold $T = s$. If they do not all hold, $T > s$ go to step 3.

**Step 3:** Given $\{N_{-i}\}_{i=1}^{s-1}$, guess that $N_t = 1 \ \forall t \geq 2$. Then determine $N_1 \in (0, 1)$ using participation constraint (35), and $N_0$ using participation constraints (35) and (36).

Verify if $N_t = 1 \ \forall t \geq 2$ by checking whether inequality (36) holds for $N_2 = 1$ through to $N_s = 1$. If these inequalities hold $T = s + 1$. If they do not all hold, $T > s + 1$ go to step 4, and so on.
Figure 1. Simulated Lifetime Earnings from Experiment 1

Figure 2. Simulated Lifetime Earnings from Experiment 2
Figure 3. Thai Average Earnings

Figure 4. Thai Population Share of Modern Sector
Figure 5. Thai Cohort Modern Share

Figure 6. Thai Inter-sectoral Earnings Inequality
Figure 7. Thai Modern Experience-Earnings Profile

Figure 8. Thai Traditional Experience-Earnings Profile
Figure 9. Thai Real Interest Rate

Figure 10. Thai Distribution of Experience Groups
Figure 11. Average Earnings Comparison

Figure 12. Average Earnings in Full-Transition Economy
Figure 13. Lifetime Earnings in Full-Transition Economy
Figure 14. Modern Cohort Share Comparison

Figure 15. Aggregate Modern Share Comparison
Figure 16. Average Earnings Ratio of Modern to Traditional

Figure 17. Labor/Experience Ratios
Figure 18. Simulated Modern Experience-Earnings Profile

Figure 19. Thai Modern Experience-Earnings Profile (Filtered)
Figure 20. Simulated Traditional Experience-Earnings Profile

Figure 21. Thai Traditional Experience-Earnings Profile (Filtered)