A Theory of Modern Transition Applied to Thailand (Preliminary)[*]

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Abstract

We consider a dual economy consisting of a traditional sector and a modern sector. Each sector uses sector-specific skill, which is accumulated through work experience. There is exogenous productivity growth only in the modern sector, which has an attractive force of shifting people toward the modern sector. However, the transition to the exclusive use of the modern sector technology occurs gradually, because experience and labor are complements within each sector. During transition, aggregate output follows a S-shaped path, eventually converging to the productivity growth of the modern sector. Using micro data from Thailand, 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. 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

Keywords: Modern Transition, Sector-Specific Complementarity, TFP and Inequality Dynamics

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1 Introduction

This paper argues that a model of transition can provide a useful theory of both why modern industrialization occurs at different times and why it proceeds slowly. An existing literature 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, e.g. Lucas (2000), Gollin, Parente and Rogerson (2002), Hansen and Prescott (2002), Ngai (2003) and Parente and Prescott (2004). This literature has mainly considered a transition from agricultural to non-agricultural technologies where the timing and speed of industrialization is explained by the built-in exogenous barriers and/or exogenous productivity growth differentials between the two sectors.

In this paper, we focus on the transition from traditional to modern technologies, which does not necessarily coincide with, though is related to, the sectoral shifts from agriculture to non-agriculture. The modern sector is identified with a group of people who benefit from exogenous productivity growth, regardless where they live and also regardless whether they work in agriculture or non-agriculture.

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) postulated a relationship between growth and inequality emphasizing the population shifts from agriculture to non-agriculture. Gollin, Parente and Rogerson (2002) provide an updated discussion, focusing on cross-country differences in income levels. Todaro (1969) is an early treatment of transition and labor productivity via rural-urban migration. Lucas (2004) provides an updated discussion.

This paper is closest to the third 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). In contrast to their original assumptions of the existence of unlimited surplus labor and an imposed inter-sectoral gap in marginal productivity of labor, 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, which are the typical feature of conventional dual-economy models.

Our model introduces sector-specific skills that can be accumulated from work experience and complement labor within each sector. As in Chari and Hopenhayn (1991), entry into the more productive modern sector by young agents who supply labor, is limited by the stock of old agents who

supply sector-specific experience, while today's entrants who supply labor determine tomorrow's stock of sector-specific experience.[1] Due to this complementarity, the transition to the exclusive use of the modern sector technology occurs gradually and the speed and the slope of the transition path depend on the initial distribution of the sector-specific skills. 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 in the model is driven by the *endogenous* evolution of the distribution of the sector-specific skills combined with the *exogenous* productivity growth in the modern sector. The output growth from the changes in sector-specific experience would enter into conventional measures of aggregate TFP growth. In this sense, our model provides a theory of TFP, as posited by Prescott (1998). The importance of TFP in explaining within-country growth experiences is well documented by Kehoe and Prescott (2002). Regarding the sources of the TFP, 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. Obviously, differences in policy may explain the differences in TFP over space and over time. However, before rushing into the policy discussion, we seek the origin of the TFP differentials from some fundamental conditions such as the initial distribution of the sector-specific skills between modern and traditional sectors. We then evaluate how far a model with no policy arguments can reach.

Our model of transition also provides a natural framework to analyze inequality dynamics within countries. After partitioning the economy into traditional and modern sectors, we document systematic differences in earnings both across sectors and within sectors, and their evolution over time. Depending on the distribution of sector-specific experience, the average earnings gap between the two sectors is determined. The within-sector experience premium schedules are also determined by the relative scarcity of sector-specific skills, hence generating within-sector inequality dynamics as the economy grows. Thus, our model provides a micro foundation of the growth-inequality nexus, i.e. the well-known Kuznets curve, postulated in Kuznets (1955).

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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.

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 the 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. 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. Some key parameters like the sector-specific complementarity between experience and labor have never been directly measured. Thus, simulating the model with a tight link to the actual data for a single country allows us to learn about not only the appropriate parameter space for the model, but also how the various general equilibrium forces of the model work through. This will lay a firm ground for future analysis of other countries as well as for future cross-country studies.

We estimate almost all the deep parameters of the model by embedding its structure to the Thai data from the earnings relationships within each sector. 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 simulates well the aggregate earnings growth path. It captures well the S-shaped transition of modern labor share. It captures well an overall increasing trend in the earnings inequality across sectors found in the data. Finally, the observed magnitude of the experience premium in the modern sector is matched by the model, while a large drop in this premium in the traditional sector between 1976 and 1996 is also captured.

The paper is organized as follows. Section 2 describes the model. Section 3 describes the data. Procedure of structural estimation is explained in Section 4. Simulation results are discussed in Section 5. Section 6 concludes.

2 Model

Consider a two period overlapping generations economy with constant population.[2] Lifetime preferences are,

$$u = c_1 + \beta c_2, \ \beta \in (0, 1) \tag{1}$$

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

$$c_1 + \beta c_2 = y_1 + \beta y_2 \tag{2}$$

Production occurs in two sectors that produce a homogenous good, a traditional sector and a modern sector. Aggregate output in period t is given by,

$$\tilde{Y}_t = \tilde{Y}_{TRADITIONAL} \left[G\left(L_{T,t}, E_{T,t}\right), K_{T,t} \right] + \tilde{Y}_{MODERN} \left[\gamma^t \tilde{X} F\left(L_{M,t}, E_{M,t}\right), K_{M,t} \right] \tag{3}$$

$G\left(L_{T,t}, E_{T,t}\right), \gamma^t X F\left(L_{M,t}, E_{M,t}\right)$ denote efficiency units of labor, and $K_{T,t}, K_{M,t}$ denote physical capital in the traditional and modern sectors respectively. In each sector, output is constant returns to scale in both inputs.

When the marginal product of capital is constant $R = \frac{1}{\beta}$, the ratio of capital to efficiency units of labor is constant. The marginal product of an efficiency unit of labor in the traditional sector is constant, and the marginal product of an efficiency unit of labor in the modern sector grows at rate γ. Define,

$$\nu_T = \frac{\partial \tilde{Y}_{TRADITIONAL}}{\partial G\left(L_{T,t}, E_{T,t}\right)}$$

$$\gamma^t \nu_M = \frac{\partial \tilde{Y}_{MODERN}}{\partial F\left(L_{M,t}, E_{M,t}\right)}$$

Define $X \equiv \frac{\nu_M}{\nu_T}$. Then, we can renormalize the measure of output to express *aggregate labor earnings* as,[3]

$$LY_t = G\left(L_{T,t}, E_{T,t}\right) + \gamma^t X F\left(L_{M,t}, E_{M,t}\right) \tag{4}$$

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 $E_{k,t}, \ k \in \{T, M\}$. Define $\varpi_T \equiv G(1, 0)$ and $\varpi_M \equiv F(1, 0)$.

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[2] We generalize the model to s period overlapping generations later in the paper.

[3] If the capital share is (i) constant and (ii) equal across sectors, the growth of labor income will equal the growth of per capita income. If the capital share is higher in the modern sector, the growth of labor income will be lower than the growth of per capita income during the transition period.

In each sector, raw labor and experience are complements so,

$$\frac{\partial^2 G\left(L_{T,t}, E_{T,t}\right)}{\partial L_{T,t}\partial E_{T,t}} \geq 0 \text{ and } \frac{\partial^2 F\left(L_{M,t}, E_{M,t}\right)}{\partial L_{M,t}\partial E_{M,t}} \geq 0 \tag{5}$$

The only identifying assumption of the modern sector is that there are sustained exogenous increases in productivity for that sector only $\gamma > 1$.[4] We assume $\beta\gamma < 1$.[5]

In a two period overlapping generations economy, the resource constraints are,

$$
\begin{aligned}
L_{T,t} &= M_t + \lambda M_{t-1} \tag{6} \\
E_{T,t} &= \lambda M_{t-1} \\
L_{M,t} &= N_t + \lambda N_{t-1} \\
E_{M,t} &= \lambda N_{t-1} \\
1 &= M_t + N_t \\
&\lambda \in (0,1], M_{-1} \in [0,1], N_{-1} \in [0,1] \; given
\end{aligned}
$$

M_{t-1} denotes the measure of agents in cohort $t-1$ who entered the traditional sector when they were born. In period $t-1$, each of these agents supplies 1 unit of raw labor to traditional sector production. In period t, each of these agents supplies λ units of raw labor and λ units of experience specific to traditional sector production. N_{t-1} denotes the measure of agents in cohort $t-1$ who entered the modern sector when they were born. In period $t-1$, each of these agents supplies 1 unit of raw labor to modern sector production. In period t, each of these agents supplies λ units of raw labor and λ units of experience specific to modern sector production. λ 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.

The resource constraints can be simplified to,

$$
\begin{aligned}
L_{T,t} &= 1 + \lambda - L_{M,t} = 1 - N_t + \lambda(1 - N_{t-1}) \\
E_{T,t} &= \lambda - E_{M,t} = \lambda\left(1 - N_{t-1}\right)
\end{aligned}
$$

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[4]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.

[5]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.

The state of the economy in period t is given by N_{t-1}. The initial state of the economy N_{-1} is exogenously given.

Define $g\left(\frac{L_{T,t}}{E_{T,t}}\right) \equiv \frac{G\left(L_{T,t},E_{T,t}\right)}{E_{T,t}}$. Then, the marginal product of labor in the traditional sector is $g'\left(\frac{L_{T,t}}{E_{T,t}}\right)$. The marginal product of experience in the traditional sector is $\phi\left(\frac{L_{T,t}}{E_{T,t}}\right) \equiv g\left(\frac{L_{T,t}}{E_{T,t}}\right) - g'\left(\frac{L_{T,t}}{E_{T,t}}\right)\frac{L_{T,t}}{E_{T,t}}$. 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 $f\left(\frac{L_{M,t}}{E_{M,t}}\right) \equiv \frac{F\left(L_{M,t},E_{M,t}\right)}{E_{M,t}}$. Then, the marginal product of labor in the modern sector is $\gamma^t X f'\left(\frac{L_{M,t}}{E_{M,t}}\right)$. The marginal product of experience in the modern sector 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 product of an agent entering the traditional sector when he is born is,

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

In period t, the lifetime product of an agent entering the modern sector when he is born is,

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

When there is no sectoral reallocation of workers,

$$N_{t-i} = N_t \in (0,1) \, \forall t - i \lessgtr t$$
$$\Rightarrow \frac{L_{T,t}}{E_{T,t}} = \frac{L_{M,t}}{E_{M,t}} = 1 + \frac{1}{\lambda}$$

Since $1 + \frac{1}{\lambda}$ is the labor experience ratio when there is no reallocation of workers across the two sectors, if $\frac{L_{T,t}}{E_{T,t}} < 1 + \frac{1}{\lambda} \Rightarrow \frac{L_{M,t}}{E_{M,t}} > 1 + \frac{1}{\lambda}$ and vice versa.

We assume that the lifetime product 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.,

$$Condition\ A \quad : \quad g'\left(1 + \frac{1}{\lambda}\right) + \beta\lambda\left[g'\left(1 + \frac{1}{\lambda}\right) + \phi\left(1 + \frac{1}{\lambda}\right)\right] \tag{7}$$
$$\leq \quad \gamma^t X\left[f'\left(1 + \frac{1}{\lambda}\right) + \beta\lambda\gamma\left[f'\left(1 + \frac{1}{\lambda}\right) + \pi\left(1 + \frac{1}{\lambda}\right)\right]\right]$$

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 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 (7).

2.1 Equilibrium

In a competitive equilibrium, 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 (4), 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,

$$\max\left\{g'\left(\frac{L_{T,t}}{E_{T,t}}\right) + \beta\lambda\left[g'\left(\frac{L_{T,t+1}}{E_{T,t+1}}\right) + \phi\left(\frac{L_{T,t+1}}{E_{T,t+1}}\right)\right], \gamma^t X\left[f'\left(\frac{L_{M,t}}{E_{M,t}}\right) + \beta\lambda\gamma\left[f'\left(\frac{L_{M,t+1}}{E_{M,t+1}}\right) + \pi\left(\frac{L_{M,t+1}}{E_{M,t+1}}\right)\right]\right]\right\}$$
(9)

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 (6),

$$g'\left(1+\frac{1-N_t}{\lambda(1-N_{t-1})}\right) + \beta\lambda\left[g'\left(1+\frac{1-N_{t+1}}{\lambda(1-N_t)}\right) + \phi\left(1+\frac{1-N_{t+1}}{\lambda(1-N_t)}\right)\right]$$
$$= \gamma^t X\left[f'\left(1+\frac{N_t}{\lambda N_{t-1}}\right) + \beta\lambda\gamma\left[f'\left(1+\frac{N_{t+1}}{\lambda N_t}\right) + \pi\left(1+\frac{N_{t+1}}{\lambda N_t}\right)\right]\right]$$
(10)

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 young agents enter the modern sector only in period $t-1$, $N_{t-1} = 1$, using Lemma 1 the

participation constraint is,

$$g'(1) + \beta\lambda \left[g'(1) + \phi(1) \right] \tag{11}$$
$$\leq \gamma^{t-1} X \left[f'\left(1 + \frac{1}{\lambda N_{t-2}}\right) + \beta\lambda\gamma \left[f'\left(1 + \frac{1}{\lambda}\right) + \pi\left(1 + \frac{1}{\lambda}\right) \right] \right]$$

Equations (10) and (11) characterize a system of differential 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 incomes are first rising slower than γ, then rising faster than γ. Once transition is complete, lifetime income grows at rate γ. Thus, the simulated outcomes describe an S-shaped path of lifetime incomes over the time series. To understand this result intuitively, suppose there is no complementarity in the modern sector so $\frac{\partial^2 F(L_{M,t}, E_{M,t})}{\partial L_{M,t} \partial E_{M,t}} = 0$. In this case, the log of lifetime income grows linearly at the steady state rate γ during and after transition. Next, suppose there is no complementarity in the traditional sector so $\frac{\partial^2 G(L_{T,t}, E_{T,t})}{\partial L_{T,t} \partial E_{T,t}} = 0$, which implies lifetime incomes are constant in the traditional sector. In this case, lifetime incomes are constant up to period $T - 2$, then they converge to the steady state lifetime income path by period T. In general, when there is complementarity in both sectors, the lifetime income follows the pattern described above.

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

(i) If lifetime income 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 income is first rising slower than γ, then rising faster than γ:

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 wage in each sector in period t is given by,

$$Traditional \quad : \quad G\left(1, \frac{1}{\frac{1-N_t}{\lambda(1-N_{t-1})}+1}\right) \frac{\frac{1-N_t}{1-N_{t-1}}+\lambda}{\frac{1-N_t}{1-N_{t-1}}+1}$$

$$Modern \quad : \quad \gamma^t X F\left(1, \frac{1}{\frac{N_t}{\lambda N_{t-1}}+1}\right) \frac{\frac{N_t}{N_{t-1}}+\lambda}{\frac{N_t}{N_{t-1}}+1}$$

When the population growth in either sector is falling, average wages in that sector must be rising. Thus, from Proposition 2(i), when lifetime income is rising average wages are rising in the traditional sector. In the modern sector, wages may be rising even when population growth is increasing, since there is productivity growth through $\gamma > 1$.

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

$$Traditional \quad : \quad \lambda\left(1 + \frac{\phi\left(1 + \frac{1-N_t}{\lambda(1-N_{t-1})}\right)}{g'\left(1 + \frac{1-N_t}{\lambda(1-N_{t-1})}\right)}\right)$$

$$Modern \quad : \quad \lambda\left(1 + \frac{\pi\left(1 + \frac{N_t}{\lambda N_{t-1}}\right)}{f'\left(1 + \frac{N_t}{\lambda N_{t-1}}\right)}\right)$$

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,

$$\max_{\{N_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t Y_t \text{ s.t. (4) and (6)} \tag{12}$$

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.

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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 role is affected by the degree of relative complementarity in the modern versus traditional sectors. In a two period overlapping generations setting, the initial share of modern experience is a single number rather than a distribution in settings 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,

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

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

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 ρ_T and ρ_M, the greater the complementarity between labor and experience. At the limit value of ρ_T and ρ_M at unity, labor and experience are perfect substitutes with relative shares being governed by the parameters α_T and α_M alone, and experience premia are measured by $(1 - \alpha_T)$ and $(1-\alpha_M)$. We may consider the parameters α_T and α_M as controlling the pure experience premium in the absence of complementarity.

Assuming people work 40 years, 1 period in our 2 period overlapping generations model corresponds to 20 years. The calibrated parameters are,

Parameter	Value	Note
β	0.045	$\simeq (0.86)^{20}$ from annual interest rate 16%, within range of Thai data
γ	1.3	$\simeq (1.013)^{20}$ average productivity growth UK, 1900-2000
λ	0.6	$\simeq (0.975)^{20}$ consistent with estimates for Thailand we report

We set modern sector productivity growth equal to aggregate productivity growth in a frontier economy such as the UK, 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.

	Experiment 1					Experiment 2			
Parameter	α_T	α_M	ρ_T	ρ_M		α_T	α_M	ρ_T	ρ_M
Value	0.8	0.8	0.5	-2		0.8	0.8	0.5	-2

We first report outcomes in Experiment 1. [Figure 6] shows the evolution of lifetime earnings with different initial shares in the modern sector, N_{-1}. [Figure 7] shows the corresponding evolution of average earnings. Two economies with $N_{-1} = 0.1, N_{-1} = 0.0001$ have negligible differences in average earnings at the initial period, but the first economy is 10 times richer 100 years later. 100 years later, this economy is 6 times richer than another with $N_{-1} = 0.01$. However, 160 years after the initial period, all economies are equally rich. Meanwhile, the difference in lifetime earnings is of lower magnitude, never exceeding 4 for the hypothetical economies considered.

The pattern of divergence then convergence of average earnings relative to the steady state economy (defined as $N_{-1} = 1$) graphed, implies economies which experience a take-off of average 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 are very different. First, the difference in lifetime incomes is significantly reduced, although the S-shaped pattern of convergence remains, and the order of lifetime incomes remains the same [Figure 8]. The difference in earnings is even more dramatic. Under the parameters used, initial average earnings are lower in the economy with higher N_{-1} [Figure 9]. Convergence in both lifetime and average 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 address this key issue for Thailand, in the estimation and simulation sections of this paper.

2.4 S-period Model

We now consider a general s-period overlapping-generations model for $2 \leq s < \infty$, which will be used in estimation and simulation of the model.[6] Lifetime preferences are,

$$u = \sum_{j=0}^{s-1} \beta^j c_j, \ \ \beta \in (0,1) \tag{13}$$

The lifetime budget constraint is now given by,

$$\sum_{j=0}^{s-1} \beta^j c_j = \sum_{j=0}^{s-1} \beta^j y_j \tag{14}$$

The sectoral production functions remain the same as in the two-period model, but the state variable is now the entire distribution of experience in modern sector over the age cohorts $\{N_{t-i}\}_{i=0}^{s-1}$, where 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:

$$L_{M,t} = \sum_{i=0}^{s-1} \lambda^i N_{t-i} \tag{15}$$

$$E_{M,t} = \sum_{i=0}^{s-1} i\lambda^i N_{t-i} \tag{16}$$

$$L_{T,t} = \sum_{i=0}^{s-1} \lambda^i M_{t-i} \tag{17}$$

$$E_{T,t} = \sum_{i=0}^{s-1} i\lambda^i M_{t-i} \tag{18}$$

$$M_{t-i} = 1 - N_{t-i}, \ \forall i \tag{19}$$

The initial condition $\{N_{-i}\}_{i=1}^{s-1}$ is exogenously given. In period t, each of these agents supplies λ^i units of labor and $i\lambda^i$ units of experience specific to traditional sector production, where $i \in \{0, 1, ..., s-1\}$. In period $t+1$, each of these agents supplies λ^{i+1} units of labor and $(i+1)\lambda^{i+1}$ units of experience specific to traditional sector production. N_{t-i} denotes the measure of agents in cohort $t-i$ who entered the modern sector when they were born. In period t, each of these agents supplies λ^i unit of labor and $i\lambda^i$ units of experience specific to modern sector production. In period $t+1$, each of these agents

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[6]Some of the analytical results only hold for the $s = 2$ case above, because of the following reasons: (i) in the two period case, the labor to experience ratio is equivalent to the population growth rate of each sector, (ii) in the two period case, the state of the economy given by the distribution of experienced agents across sectors is a single number.

supplies λ^{i+1} units of labor and $(i+1)\lambda^{i+1}$ units of experience specific to modern sector production.[7]

In period t, the lifetime earnings of an agent entering the traditional sector or modern sector respectively are given by,

$$Traditional \quad : \quad \sum_{j=0}^{s-1}(\beta\lambda)^j\left[g'\left(\frac{L_{T,t+j}}{E_{T,t+j}}\right)+j\phi\left(\frac{L_{T,t+j}}{E_{T,t+j}}\right)\right] \tag{20}$$

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

When there is no sectoral reallocation of workers,

$$
\begin{aligned}
N_{t-i} \quad &= \quad N_t \in (0,1) \;\forall t-i \lessgtr t \\
\Rightarrow \quad \frac{L_{T,t}}{E_{T,t}} &= \frac{L_{M,t}}{E_{M,t}} = \frac{\sum_{i=0}^{s-1}\lambda^i}{\sum_{i=0}^{s-1}i\lambda^i} = \frac{\frac{1-\lambda^s}{1-\lambda}}{\frac{\frac{\lambda-\lambda^s}{1-\lambda}-(s-1)\lambda^s}{1-\lambda}} = \frac{(1-\lambda^s)(1-\lambda)}{\lambda-\lambda^s-(s-1)\lambda^s(1-\lambda)} \equiv l^* \text{ constant}
\end{aligned}
$$

Since l^* is the labor-experience ratio when there is no reallocation of workers across the two sectors, if $\frac{L_{T,t}}{E_{T,t}} < l^* \Rightarrow \frac{L_{M,t}}{E_{M,t}} > l^*$ and vice versa.

Condition A is now replaced by Condition A$'$,

CONDITION A$'$: $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ (21)

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

X_{IR} is given by,

$$\sum_{j=0}^{s-1}(\beta\lambda)^j\left[g'(l^*)+j\phi(l^*)\right] = X_{IR}\sum_{j=0}^{s-1}(\beta\lambda)^j\gamma^j\left[f'(l^*)+j\pi(l^*)\right] \tag{22}$$

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

3   Data

We use the Thai Socio-Economic Survey (SES), a *nationally representative* household survey conducted by the National Statistical Office for the 1976-1996 period. 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

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[7] $\frac{\partial^2 F}{\partial N_{t-i}\partial N_{t-j}} = \frac{\partial}{\partial N_{t-j}}\lambda^i\left[f'(l)+i\pi(l)\right] = f''(l)\lambda^i\left[1-il\right]\frac{dl}{dN_{t-j}} = \left\{\frac{f''(l)}{E_{M,t}}\lambda^i\lambda^j\right\}\left[1-il\right]\left[1-jl\right]$. Since $\left\{\frac{f''(l)}{E_{M,t}}\lambda^i\lambda^j\right\} < 0$, N_{t-i} and N_{t-j} are complements when $\left[1-il\right]\left[1-jl\right] < 0$, and substitutes when $\left[1-il\right]\left[1-jl\right] \geq 0$. Thus, cohorts which are separated more in time are more likely to be complementary.

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.

[Figure 1] 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 2] shows how the share of the workforce across sectors evolved over the period. Clearly, the period under consideration was one of gradual but significant structural change for the Thai economy.

This partition of the aggregate data yielded a number of systematic inter and intra sectoral differences in earnings. [Figure 3] shows how the ratio of modern to traditional average earnings across sectors evolved over the period. Average earnings is about 1.5 times higher in the modern sector and there is a slight upward trend during the sample period. [Figure 4] and [Figure 5] show how the experience-earnings profiles for each sector has evolved between 1976 and 1996. It appears that the experience premium is higher in the traditional sector. In the traditional sector there is a clear fall in the experience premium between 1976 and 1996, while in the modern sector this is less clear.

4 Estimation

4.1 Sector Partition

The relevant concept of income in the model is *earnings* rather than all-inclusive income. The disaggregated data of income combined with the individual working status data 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.[8]

There are two types of heterogeneity in the model, (i) sector type 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. We combine the disaggregated feature of the micro data, with the implications of the model to identify the modern-tradition partition of the workforce.

Essentially, we follow a guess-and-verify strategy. First, we disaggregate the workforce using three-digit occupational category data combined with industry sector data, and compute the rates of change in workforce 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 for this occupation. The ranking of the occupational categories ordered by the rates of change in workforce share is 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. Thus, 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

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[8]The size of this selected sample is 176,666 individuals including all years.

is properly partitioned, we would 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.

There are also caveats 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 workforce share of employees may increase while that of employers or the self-employed may decrease over time within a sector using the same technology. The model is silent about this kind of compositional change but we need to categorize both groups of people into the same sector.

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 hired 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. We verify the appropriateness of this partition by observing the estimated sectoral exogenous growth rates.

In the literature of structural transformation, the typical partitioning characteristics are either

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rural versus urban as in Todaro (1969) and Lucas (2004) or agriculture versus non-agriculture (in particular manufacturing) as in Kuznets (1966), Hansen and Prescott (2000), and Gollin, Parente and Rogerson (2004). Our chosen partition of the "modern" sector suggests that this sector does not necessarily correspond to urban areas or manufacturing. "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.

The modern and traditional sectors coexist in both rural and urban areas. 38% of the urban population belongs to the traditional sector and 12% of the rural population belongs to the modern sector. The two sectors coexist in agriculture, manufacturing, and services. The major agricultural activity in Thailand is rice farming, and most agricultural workers and farmers are included in the traditional sector. However, 1.3% of the agricultural population like fishermen (shrimp farmers), non-logging forest workers, dairy and other field-crop farmers belong to the modern sector.

38% of manufacturing workers are traditional. These traditional manufacturing workers include miners, metal rolling mill workers, wood and paper product makers, spinners and weavers, grain millers, sugar processors and refiners, tobacco makers, tailors, blacksmith, rubber product makers, and printing pressmen. Modern manufacturing workers include construction workers, material handling and equipment operators, electrical and electronic workers, sheet metal makers, jewelry and precious metal makers, shoe makers, pattern makers, embroiders, potters, and food and beverage processors other than grain millers and sugar processors.

79% of service workers are traditional sector. The traditional service workers include self-employed traders, street and waterway vendors, professional midwives and occupational therapists, cooks and maids, drivers, primary and secondary school teachers, policemen, and armed forces. Modern service workers include book-keepers and accountants, communication service workers, technical salesmen, commercial travel agencies, insurance, real estate, security service salesmen, medical doctors and nurses, pre-school and university-or-higher level teachers, firemen, mechanics and repairmen, and dockers and freight handlers. It is interesting to notice that university-or-higher level teachers and pre-school teachers turn out to be categorized into the modern sector while primary and secondary 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. These examples illustrate that modern and traditional sectors may coexist even within the same type of industry, in particular among the service workers.

4.2 Earnings Functions

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

$$Traditional \quad : \quad G\left(L_{T,t}, E_{T,t}\right) = \left[\alpha_T L_{T,t}^{\rho_T} + (1 - \alpha_T) E_{T,t}^{\rho_T}\right]^{\frac{1}{\rho_T}} \tag{23}$$

$$Modern \quad : \quad F\left(L_{M,t}, E_{M,t}\right) = \left[\alpha_M L_{M,t}^{\rho_M} + (1 - \alpha_M) E_{M,t}^{\rho_M}\right]^{\frac{1}{\rho_M}} \tag{24}$$

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

$$\tilde{w}_{T,jt} = (\lambda_T)^j (\gamma_T)^t \left[\alpha_T \left(\frac{L_{T,t}}{E_{T,t}}\right)^{\rho_T} + (1 - \alpha_T)\right]^{\frac{1}{\rho_T} - 1} \left[\alpha \left(\frac{L_{T,t}}{E_{T,t}}\right)^{\rho_T - 1} + j(1 - \alpha_T)\right] \tag{25}$$

where λ_T denotes the depreciation rate and γ_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 γ_T to be non-zero in our estimation. If the sector partitioning is correct, the estimated γ_T should be close to zero.

From the CES specification in (24), the modern sector earnings $\tilde{w}_{M,jt}$ of an agent with j periods of experience at date t is,

$$\tilde{w}_{M,jt} = (\lambda_M)^j (\gamma_M)^t X \left[\alpha_M \left(\frac{L_{M,t}}{E_{M,t}}\right)^{\rho_M} + (1 - \alpha_M)\right]^{\frac{1}{\rho_M} - 1} \left[\alpha_M \left(\frac{L_{M,t}}{E_{M,t}}\right)^{\rho_M - 1} + j(1 - \alpha_M)\right] \tag{26}$$

where λ_M denotes the depreciation rate, γ_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 (15) to (18).

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 χ_{it} in both sectors. We also assume $z_k(\chi_{k,it}, \epsilon_{k,it})$ to take the exponential form such that,

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

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,

$$Traditional \quad : \quad \ln w_{T,it} = j \ln \lambda_T + t \ln \gamma_T + \Psi\left(\frac{L_{T,t}}{E_{T,t}}, j; \alpha_T, \rho_T\right) + A_T\chi_{T,it} + \epsilon_{T,it} \tag{27}$$

$$Modern \quad : \quad \ln w_{M,it} = j \ln \lambda_M + t \ln \gamma_M + \ln X + \Phi\left(\frac{L_{M,t}}{E_{M,t}}, j; \alpha_M, \rho_M\right) + A_M\chi_{T,it} + \epsilon_{M,it} \tag{28}$$

where,

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

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

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 (27) and (28) 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 ρ_T and ρ_M at unity, the sectoral labor-experience ratio $\frac{L_{k,t}}{E_{k,t}}$ drops from the sectoral earnings equations (25) and (26).

4.2.1 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 (27) and (28). 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 (**??**) and (24). 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 (27) and (28) 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 a right 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 (27) and (28). In the traditional log-earnings equation (27), the terms $j \ln \lambda_T$ and $t \ln \gamma_T$ are additively separable and can be identified. The remaining parameters α_T and ρ_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 α_T, the complementarity parameter ρ_T can be identified from the

time-series variation of $\frac{L_{T,t}}{E_{T,t}}$ from the pooled data over time. Therefore, all the technology parameters in the traditional sector can be identified. The same identification strategy applies to the modern sector.

4.3 Estimates

We use the nonlinear-least-squares method to estimate the sectoral log-earnings equations in (27) and (28). 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, 0.4534 for the modern sector and 0.3492 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 γ_T is indeed close to zero while that of modern sector γ_M is substantially higher than zero at 2.2% per annum. The depreciation factors λ_T and λ_M are quite similar between the traditional and modern sectors.

The estimates of ρ_T and ρ_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 -4.2433 than in the modern sector at -0.8801. 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 the prices are uniformly higher in the traditional sector than in the modern sector for all characteristics.

Table 1. Estimates for Technology Parameters

Sector	α_M, α_T	ρ_M, ρ_T	γ_M, γ_T	λ_M, λ_T	R^2	$RMSE$	#Obs.
Modern	0.0921	-1.0101	0.0233	0.9536	0.4533	0.7698	38,847
	(0.0337)	(0.2406)	(0.0008)	(0.0013)			
Traditional	0.0002	-3.8786	-0.0011	0.9626	0.3487	0.9642	137,819
	(0.0001)	(0.2835)	(0.0005)	(0.0008)			

Table 2. Estimates for Control Variables

Sector	Schooling	Male	Urban	North	Central	South	Bangkok
Modern	0.1281	0.3012	0.2132	0.0686	0.3232	0.2297	0.6275
	(0.0010)	(0.0083)	(0.0104)	(0.0147)	(0.0138)	(0.0163)	(0.0141)
Traditional	0.1431	0.4700	0.5826	0.1076	0.4432	0.4795	0.7788
	(0.0009)	(0.0055)	(0.0093)	(0.0071)	(0.0075)	(0.0087)	(0.0109)

5   Simulation

We take $s = 20$ to match the estimated parameters with the simulation, so each period lasts 2 years. We set calender year 1976 as $t = 0$ in the model. The state of the Thai economy in 1976 is $\{N_{DATA,i}\}_{i=1938}^{1974}$: the share of cohort entry into the modern sector before 1976.

Table 3. State of Thai economy in 1976

N_{1938}	N_{1940}	N_{1942}	N_{1944}	N_{1946}	N_{1948}	N_{1950}	N_{1952}	N_{1954}	N_{1956}
0.032	0.039	0.045	0.051	0.057	0.063	0.07	0.077	0.084	0.091

N_{1958}	N_{1960}	N_{1962}	N_{1964}	N_{1966}	N_{1968}	N_{1970}	N_{1972}	N_{1974}	N_{1976}
0.099	0.107	0.116	0.126	0.137	0.148	0.161	0.176	0.191	0.24

From the estimation, we take 7 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 $\beta = \frac{1}{R}$ from Thai data on interest rates. [Figure 10] shows that over the sample period, the Thai commercial bank lending rate has fluctuated between 11% and 17% with an average of 14%. We use the average interest rate which implies the two year discount factor $\beta = \left(\frac{1}{1.14}\right)^2 = 0.77$.

Using these estimates we calibrate X_{1976} to match the simulated $\hat{N}_{1976}$ to the actual N_{1976}. The standard errors of the estimates guide us in finding an appropriate parameter space.

Since we do not have panel data we cannot directly confirm the model prediction that entrants into each sector remain in that sector for the rest of their lives. [Figure 11] provides some indirect evidence. Displayed are the shares of workers across experience groups measured at different years. When there is no substantial entry/exit across sectors by experienced workers, we should observe an exact overlap across years. The data suggest they are indeed very close.

[Figure 12] shows that labor market participation in the Thai economy is stable between the experience years 0-20. Then participation falls monotonically to about 50% of its peak value for the 40 year experience group. We incorporate this demographic structure of labor market participation into the simulation, by assuming the participation rate is constant between the 0-20 year experience group, then assuming the participation rate falls linearly to 50% for the 40 year experience group.

5.1 Simulation Results

Given the calibrated X_{1976}, initial distribution and the estimated parameters, the result of the simulation is the list $\left\{ \{N_i\}_{i=1976}^{T}, T \right\}$: the simulated cohort shares and the first period of full cohort entry into the modern sector. When appropriate, the simulation results are compared with data which filter out the effect of the control variables {schooling, gender, community type, geographic region}. We refer to such data as "filtered-data".

Average labor earnings dynamics. The filtered earnings data displays the similar acceleration as in the raw earnings data [Figure 13] . The model does not predict as pronounced an acceleration in earnings as in the filtered data, but we cannot rule out the possibility that the data displays cyclical fluctuations around the predicted path of the model.

[Figure 14] compares the simulated path of average earnings in the modern and traditional sectors versus overall average earnings. Note that average earnings are initially lower in the modern sector. As the economy undertakes compositional change from the traditional to modern sector, the overall earnings displays a S-shaped path. Eventually, the overall earnings path will converge to that of a full transition economy displayed in the same Figure.

The lower average earnings in the economy with completed transition does not imply welfare is lower in that economy. The correct measure of welfare in the context of the model is lifetime earnings. [Figure 15] compares lifetime earnings in the simulated Thai economy versus that for an economy with completed transition. A necessary condition for transition to the modern sector is lifetime incomes are higher in an economy where everyone is working in the modern sector, and this is shown in the Figure.

Transition of the labor force. The model simulates cohort entry into the modern sector from 1976 onwards. The simulation overpredicts entry into the modern sector [Figure 16]. The first year at which the entire cohort is predicted to enter the modern sector is $T = 2000$. [Figure 17] shows how the

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model generates an S-shaped transition of labor share in the modern sector. Since, the simulations overpredict entry into the modern sector, the simulated labor share is higher than in the data.

Inter-industry earnings inequality. [Figure 18] compares the model outcomes with data for the ratio of modern average earnings over traditional average earnings. The filtered-data displays significantly less inter-sectoral earnings inequality than in the raw data. [Figure 18] compares the dynamics of the ratio of modern to traditional average earnings in the model to 2 benchmarks from the filtered-data. "Filtered-data1" is the data assuming no difference in the earnings coefficients for the dummy control group. "Filtered-data2" is the filtered-data imposing $X = 1$. Since the simulated ratio is always above "Filtered-data2", the calibrated X is consistent with the estimation iff it is greater than 1. The calibrated $X = 1.34$. Comparing the three time series, the model captures well the upward trend in inter-sectoral inequality during the sample period, and predicts an accelerated increase in this inequality.

Intra-industry earnings inequality. [Figure 19] shows the model overpredicts the level of labor-experience in the modern sector and underpredicts it in the traditional sector. In the simulation the labor-experience ratio peaks around 1986, while the data also displays a trend of peaking but at a later period of 1990. In the traditional sector, the labor-experience ratio is monotonically falling in the model, but this is less evident in the data.

The labor-experience ratio, in conjunction with the depreciation of labor $\left\{\lambda^M, \lambda^T\right\}$, determine the experience-earnings profile in the model. [Figure 20] and [Figure 21] plot experience-earnings profiles in 1976 and 1996 for each sector. The wage of individuals with zero experience is normalized to 1.

A remarkable observation from the actual data is how in both sectors and in both periods the experience premium gets magnified in the filtered-data. Much of this comes from the fact that younger agents acquire more schooling than older agents. In filtered-data, the experience earnings profile is steeper in the modern sector, whereas in the raw data it was steeper in the traditional sector. In the model, the modern sector experience premium is higher in 1996 than in 1976, while in the filtered-data the opposite appears to be the case. The change in the experience premium from 1976 to 1996 is much more pronounced in the traditional sector, where the model correctly predicts a fall in the experience premium, although the model overpredicts this fall.

6 Conclusion

This paper has shown how incorporating sector specific experience is important in understanding earnings levels and inequality dynamics in transition economies. We find the model simulates well the aggregate earnings growth path. It captures well the S-shaped transition of modern labor share. It captures well an overall increasing trend in the earnings inequality across sectors found in the data. Finally, the observed magnitude of the experience premium in the modern sector is matched by the model, while a large drop in this premium in the traditional sector between 1976 and 1996 is also captured.

An overall lesson is the finding of complementarity between young and old workers, which differs across sectors. This can provide a source of measured TFP and inequality dynamics.

A remaining issue in the analysis is how the growth of earnings in the data and model since the 1980s can be reconciled with the growth of Thai per capita incomes since the 1950s (see Maddison, 2001). Earnings and per capita income differ because of physical capital. In particular, 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. 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 decision would slow down the transition toward the modern sector. Currently, the model overpredicts the speed of transition toward the modern sector.

Finally, future work should look at more countries with nationally representative micro data as used here.

References

[1] Chari, V.V and Hugo Hopenhayn (1991), "Vintage Human Capital, Growth and the Diffusion of New Technology," *Journal of Political Economy*, vol. 99, no. 6, pp. 1142-1165.

[2] Clark, Colin (1940), *The Conditions of Economic Progress*, London: Macmillan.

[3] Beaudry, Paul and Patrick Francois (2004), "On-The-Job Skills Acquisition and Growth Miracles," UBC mimeo.

[4] Gollin, Douglas, Stephen Parente and Richard Rogerson (2002), "The Role of Agriculture in Development," *American Economic Review* P&P, pp. 160-164.

[5] Hansen, Gary and Ed Prescott (2002), " Malthus to Solow," *American Economic Review*, vol. 92, pp. 1205-1217.

[6] Kehoe, Timothy J., and Edward C. Prescott (2002), "Great Depressions of the Twentieth Century," *Review of Economic Dynamics*, V. 5: 1-18.

[7] Kuznets, Simon (1955), "Economic Growth and Income Inequality," *American Economic Review, Papers and Proceedings*, V. 45: 1-28.

[8] Kuznets, Simon (1966), *Modern Economic Growth*, New Haven: Yale University Press.

[9] Lewis, W. Arthur (1954), "Economic Development with Unlimited Supplies of Labor," *Manchester School of Economic and Social Studies*, vol. 22, pp. 139-191.

[10] Lucas, Robert E. (2000), "Some Macroeconomics for the 21st Century," *Journal of Economic Perspectives*, vol. 14(1), pp. 159-168.

[11] Lucas, Robert E. (2004), "Life Earnings and Rural-Urban Migration," *Journal of Political Economy*, vol. 112, no. S1.

[12] Maddison, Angus (2001), *The World Economy, A Millenial Perspective*, Paris: Development Centre of the OECD.

[13] Ngai, Rachel (2003), "Barriers and Transition to Modern Growth," *Journal of Monetary Economics forthcoming*.

[14] Parente, Stephen L. and Edward C. Prescott (2004), "A Unified Theory of the Evolution of International Income Levels," *Handbook of Economic Growth forthcoming*.

[15] Prescott, Edward C. (1998), "Needed: A Theory of Total Factor Productivity," *International Economic Review*, V.39: 525-552.

[16] Ranis, G. and J. Fei (1961), "A Theory of Economic Development," *American Economic Review*, vol. 51, pp. 533-565.

[17] Todaro, Michael P. (1969), "A Model of Labor Migration and Urban Unemployment in Less Developed Countries," *American Economic Review*, vol. 59, pp. 138-148.

A Proofs

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

$$g'(1) + \beta\lambda\left[g'(1) + \phi(1)\right]$$

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

$N_t < 1$ implies,

$$\varpi_T + \beta\lambda\left[g'\left(1 + \frac{1 - N_{t+1}}{\lambda(1 - N_t)}\right) + \phi\left(1 + \frac{1 - N_{t+1}}{\lambda(1 - N_t)}\right)\right]$$

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

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

$$g'\left(1 + \frac{1}{\lambda(1 - N_{j-1})}\right) + \beta\lambda\left[g'\left(1 + \frac{1}{\lambda}\right) + \phi\left(1 + \frac{1}{\lambda}\right)\right]$$

$$\geq \quad \gamma^j X\left\{f'(1) + \beta\lambda\gamma\left[f'(1) + \pi(1)\right]\right\}$$

Which contradicts Condition A when noting that,

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

$$> \quad f'(1) + \beta\lambda\gamma\left[f'(1) + \pi(1)\right]$$

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 $\forall t \geq 2$,

$$g'\left(1 + \frac{1 - N_0}{\lambda(1 - N_{-1})}\right) + \beta\lambda\left[g'\left(1 + \frac{1 - N_1}{\lambda(1 - N_0)}\right) + \phi\left(1 + \frac{1 - N_1}{\lambda(1 - N_0)}\right)\right]$$

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

$$g'\left(1 + \frac{1 - N_1}{\lambda(1 - N_0)}\right) + \beta\lambda\left[g'(1) + \phi(1)\right]$$

$$= \quad X\gamma\left[f'\left(1 + \frac{N_1}{\lambda N_0}\right) + \beta\lambda\gamma\left[f'\left(1 + \frac{1}{\lambda N_1}\right) + \pi\left(1 + \frac{1}{\lambda N_1}\right)\right]\right]$$

Since $\frac{1}{N_1} > 1$, from (7) we must have $\frac{N_1}{N_0} > 1 \Rightarrow \frac{N_0}{N_{-1}} > 1$ 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 $\{N_0, ..., N_{T-1}, T\}$ there exists another equilibrium $\{N'_0, ..., N'_{T'-1}, T'\}$ where $T' > T$. Then $\frac{1}{N'_{T'-1}} > 1 \Rightarrow \frac{N'_{T'-1}}{N'_{T'-2}} > 1$ and $\frac{N'_T}{N'_{T-1}} > \frac{1}{N_{T-1}}$ and $\frac{N'_{T-1}}{N'_{T-2}} > \frac{N_{T-1}}{N_{T-2}}$ by induction using the participation constraints. Using the participation constraints repeatedly this implies, $\frac{N'_0}{N_{-1}} > \frac{N_0}{N_{-1}}$. We know from the condition for T of the original equilibrium, $N'_{T-1} < N_{T-1} \Rightarrow N'_{T-2} < N_{T-2}$ and so on until $N'_0 < N_0$ which is a contradiction.

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

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

$$
g'\left(1 + \frac{1 - N_1}{\lambda(1 - N_0)}\right) + \beta\lambda\left[g'\left(1 + \frac{1 - N_1}{\lambda(1 - N_0)}\right) + \phi\left(1 + \frac{1 - N_2}{\lambda(1 - N_1)}\right)\right]
$$
$$
< \quad ... < g'\left(1 + \frac{1 - N_{T-2}}{\lambda(1 - N_{T-3})}\right) + \beta\lambda\left[g'\left(1 + \frac{1 - N_{T-1}}{\lambda(1 - N_{T-2})}\right) + \phi\left(1 + \frac{1 - N_{T-1}}{\lambda(1 - N_{T-2})}\right)\right]
$$
$$
< \quad g'\left(1 + \frac{1 - N_{T-1}}{\lambda(1 - N_{T-2})}\right) + \beta\lambda\left[g'(1) + \phi(1)\right]
$$

$\frac{1 - N_{T-1}}{1 - N_{T-2}} > 0 \Rightarrow \frac{1 - N_{T-2}}{1 - N_{T-3}} > \frac{1 - N_{T-1}}{1 - N_{T-2}}$ 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 γ,

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

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

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

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, $Q < S$.

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 $t < S$,

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

Which then implies $\frac{N_{Q+1}}{N_Q} > \frac{N_{Q+2}}{N_{Q+1}}$, and so on by induction.

By construction $\frac{N_{Q-1}}{N_{Q-2}} < \frac{N_Q}{N_{Q-1}}$. During transition, for $t < S$,

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

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 γ, and after period T, it grows at rate γ. Thus, $Q < S \leq T - 1$.

There are three possibilities for the path of $\frac{N_{t+1}}{N_t}$: (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. ∎

A.1   Equilibrium for S-period Model

In a competitive equilibrium, 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 (13) given the interest factor R, wages implied by (4), the distribution of labor across sectors in period t, $\{N_{t-i}\}_{i=1}^{s-1}, \{M_{t-i}\}_{i=1}^{s-1}$, the expected distribution of labor across sectors in periods $t+j$, $\left\{N_{t+j-i}^e\right\}_{i=1}^{s-1}, \left\{M_{t+j-i}^e\right\}_{i=1}^{s-1} j \in \{1,...,s-1\}$, and budget constraint (14),

(iii) agents expectations coincide with equilibrium outcomes,

$$\{N_{t+j-i}\}_{i=1}^{s-1} = \left\{N_{t+j-i}^e\right\}_{i=1}^{s-1} \text{ and } \{M_{t+j-i}\}_{i=1}^{s-1} = \left\{M_{t+j-i}^e\right\}_{i=1}^{s-1} \quad j \geq 1$$

(iv) the resource constraints (15)-(19) 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,

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

(29)

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 (15)-(19),

$$\sum_{j=0}^{s-1} (\beta\lambda)^j \left[g'\left(\frac{\frac{1-\lambda^s}{1-\lambda} - \sum_{i=0}^{s-1} \lambda^i N_{t+j-i}}{\frac{\lambda-\lambda^s}{1-\lambda}-(s-1)\lambda^s} - \sum_{i=0}^{s-1} i\lambda^i N_{t+j-i} \right) + j\phi\left(\frac{\frac{1-\lambda^s}{1-\lambda} - \sum_{i=0}^{s-1} \lambda^i N_{t+j-i}}{\frac{\lambda-\lambda^s}{1-\lambda}-(s-1)\lambda^s} - \sum_{i=0}^{s-1} i\lambda^i N_{t+j-i} \right) \right] \quad (30)$$

$$= \gamma^t X \sum_{j=0}^{s-1} (\beta\lambda)^j \gamma^j \left[f'\left(\frac{\sum_{i=0}^{s-1} \lambda^i N_{t+j-i}}{\sum_{i=0}^{s-1} i\lambda^i N_{t+j-i}} \right) + j\pi\left(\frac{\sum_{i=0}^{s-1} \lambda^i N_{t+j-i}}{\sum_{i=0}^{s-1} i\lambda^i N_{t+j-i}} \right) \right]$$

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 (29), $N_{t-(s-1)} = 1$ through to $N_{t-1} = 1$ implies,

$$g'\left(\frac{1}{s-1} \right) + \sum_{j=1}^{s-1} (\beta\lambda)^j \left[g'\left(\frac{1}{j} \right) + j\phi\left(\frac{1}{j} \right) \right]$$

$$\leq \gamma^{t-1} X \left[f'\left(\frac{\frac{1-\lambda^s}{1-\lambda} + \lambda^{s-1}(N_{t-s} - 1)}{\frac{\lambda-\lambda^s}{1-\lambda}-(s-1)\lambda^s + (s-1)\lambda^{s-1}(N_{t-s}-1)} \right) + \sum_{j=1}^{s-1} (\beta\lambda)^j \gamma^j \left[f'(l^*) + j\pi(l^*) \right] \right]$$

Since $g''(\cdot) < 0$, $f''(\cdot) < 0$, and $N_{t-s} < 1 \Rightarrow \frac{\frac{1-\lambda^s}{1-\lambda}+\lambda^{s-1}(N_{t-s}-1)}{\frac{\lambda-\lambda^s}{1-\lambda}-(s-1)\lambda^s + (s-1)\lambda^{s-1}(N_{t-s}-1)} > l^*$, this condition implies the condition for $N_t = 1$,

$$\sum_{j=0}^{s-1} (\beta\lambda)^j \left[g'\left(\frac{1}{j} \right) + j\phi\left(\frac{1}{j} \right) \right] \leq \gamma^t X \sum_{j=0}^{s-1} (\beta\lambda)^j \gamma^j \left[f'(l^*) + j\pi(l^*) \right]$$

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, $N_t = 1$,

$$\sum_{j=0}^{s-1} (\beta\lambda)^j \left[g'\left(\frac{\frac{1-\lambda^s}{1-\lambda} - \sum_{i=0}^{s-1} \lambda^i N_{t+j-i}}{\frac{\lambda-\lambda^s}{1-\lambda}-(s-1)\lambda^s} - \sum_{i=0}^{s-1} i\lambda^i N_{t+j-i} \right) + j\phi\left(\frac{\frac{1-\lambda^s}{1-\lambda} - \sum_{i=0}^{s-1} \lambda^i N_{t+j-i}}{\frac{\lambda-\lambda^s}{1-\lambda}-(s-1)\lambda^s} - \sum_{i=0}^{s-1} i\lambda^i N_{t+j-i} \right) \right] \quad (31)$$

$$\leq \gamma^t X \sum_{j=0}^{s-1} (\beta\lambda)^j \gamma^j \left[f'\left(\frac{\sum_{i=0}^{s-1} \lambda^i N_{t+j-i}}{\sum_{i=0}^{s-1} i\lambda^i N_{t+j-i}} \right) + j\pi\left(\frac{\sum_{i=0}^{s-1} \lambda^i N_{t+j-i}}{\sum_{i=0}^{s-1} i\lambda^i N_{t+j-i}} \right) \right]$$

In the $s = 2$ model there was a single terminal vintage condition. In the general model, there are $(s-1)$ terminal vintage conditions. (30) and (31) characterize a system of differential equations in N_t of order $2(s-1)$.

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 (31) 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 (31) 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 (30). 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 (31) 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 (30), and N_0 using participation constraints (30) and (31).

Verify if $N_t = 1 \; \forall t \geq 2$ by checking whether inequality (31) 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.
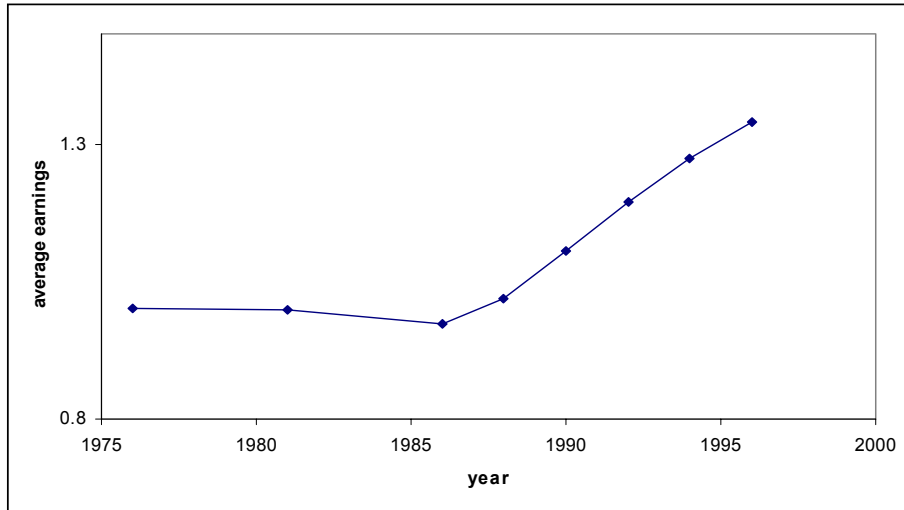
Figure 1: Thai average earnings 1976-1996
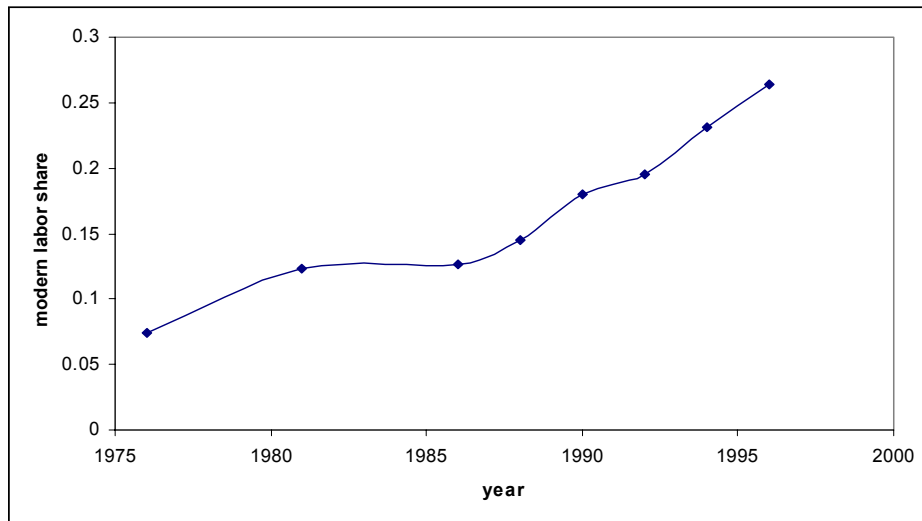
Figure 2: Modern labor share
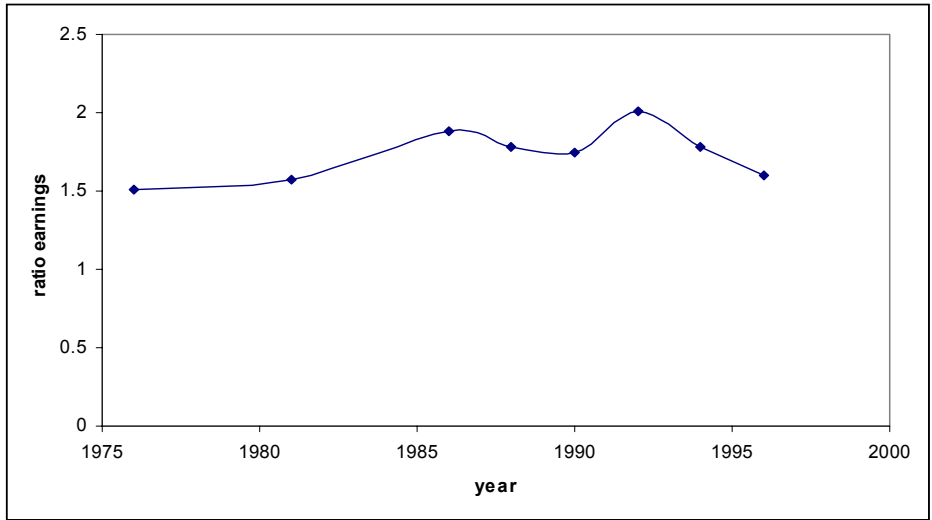
Figure 3: Inter-sectoral earnings inequality
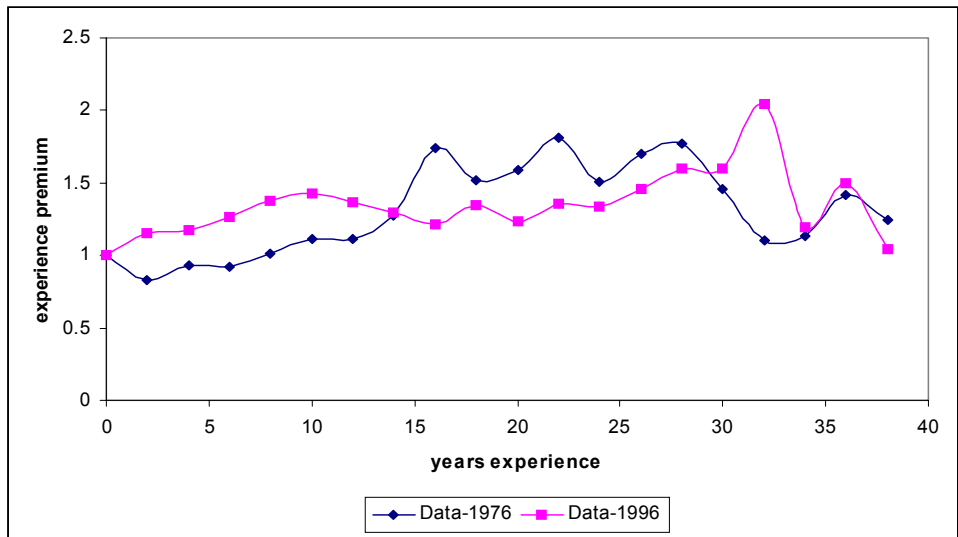
Figure 4: Modern experience premium: 1976, 1996

2
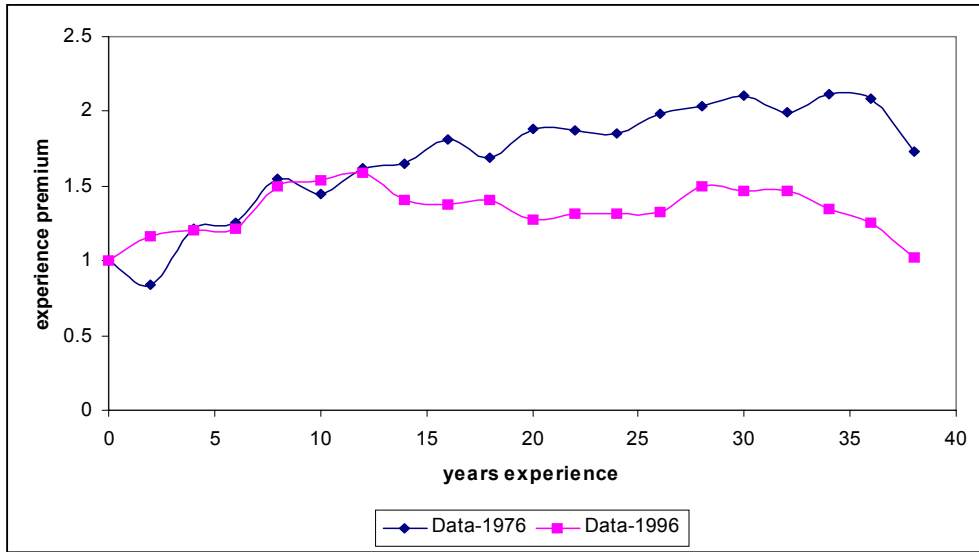
Figure 5: Traditional experience premium: 1976, 1996
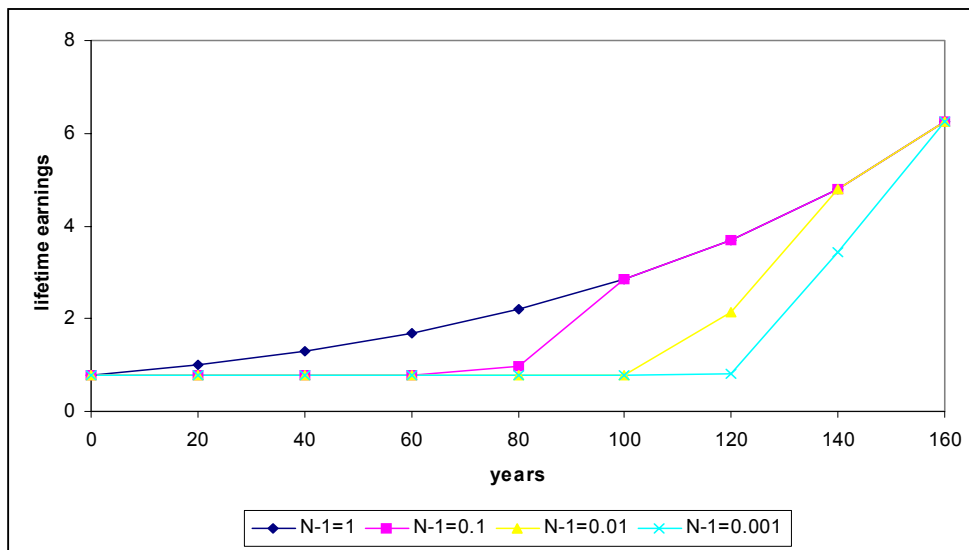
Figure 6: Lifetime earnings

3
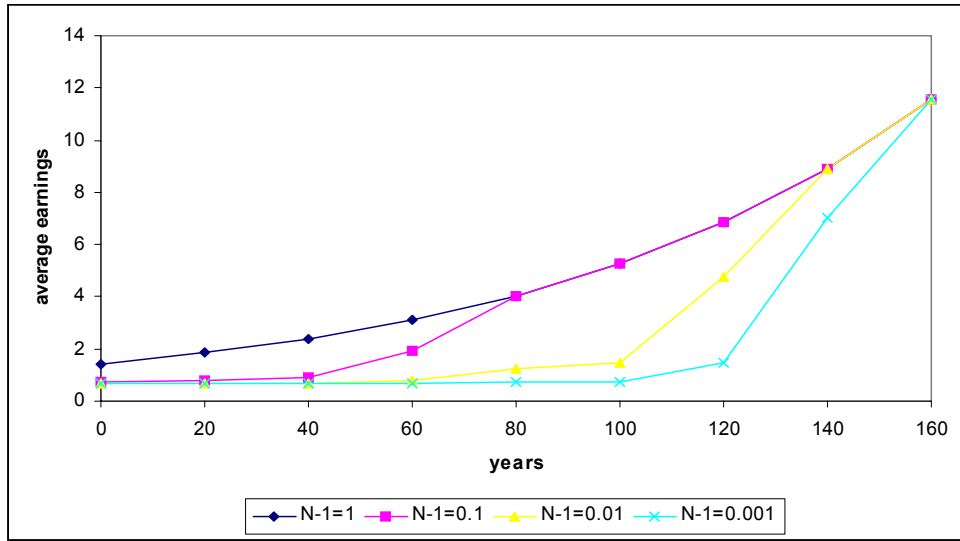
Figure 7: Average earnings
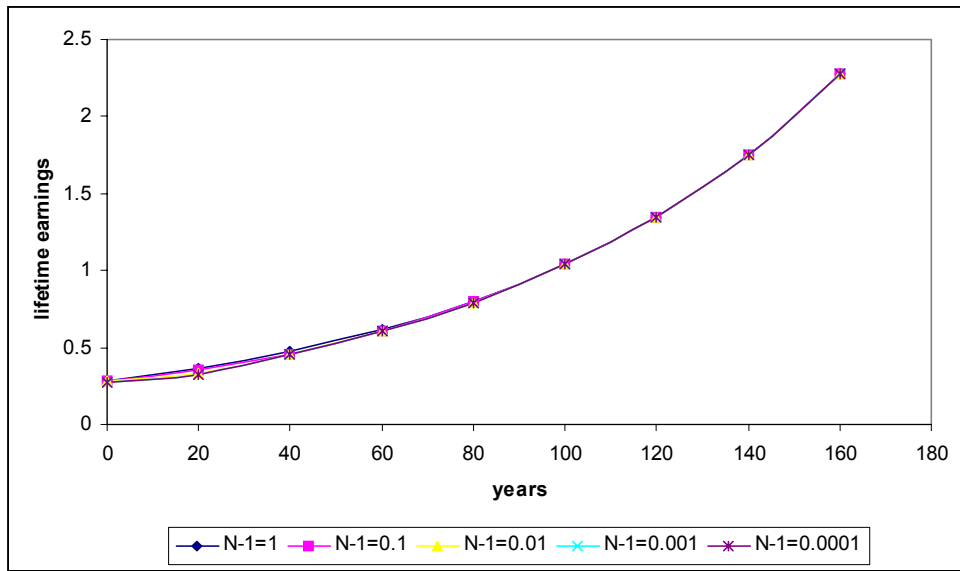
Figure 8: Lifetime earnings

4
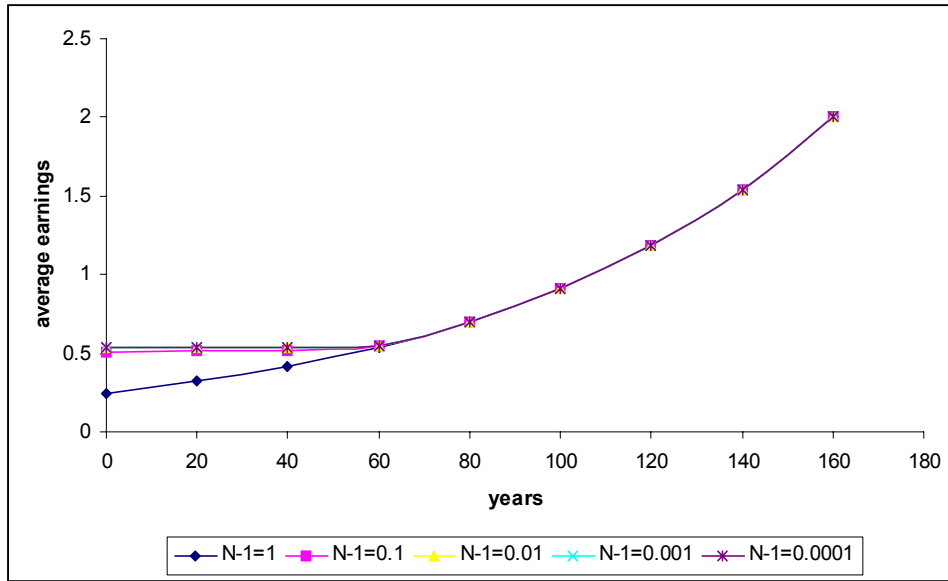
Figure 9: Average earnings
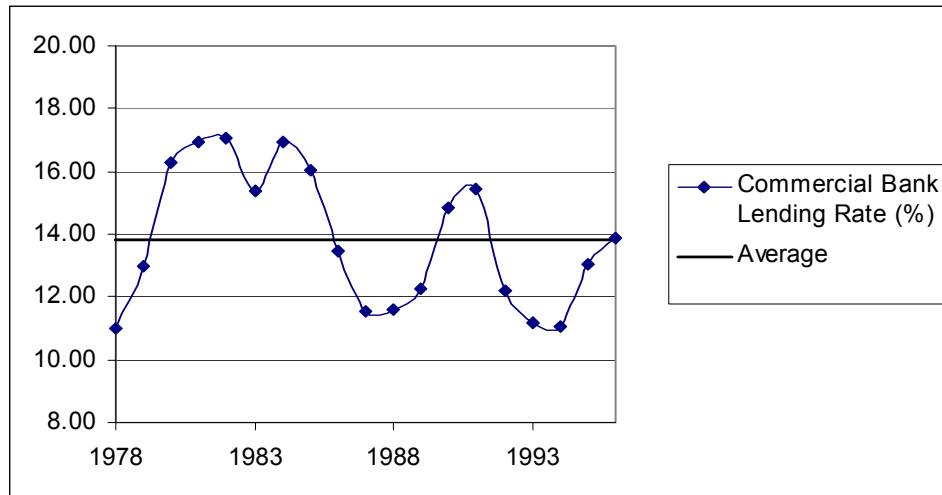
Figure 10: Thai real interest rate

5
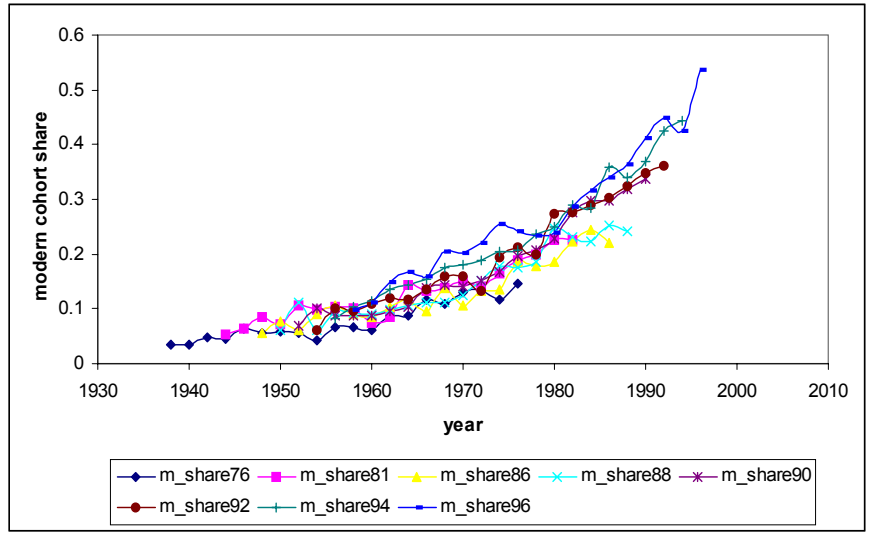
Figure 11: Cohort transition into modern sector
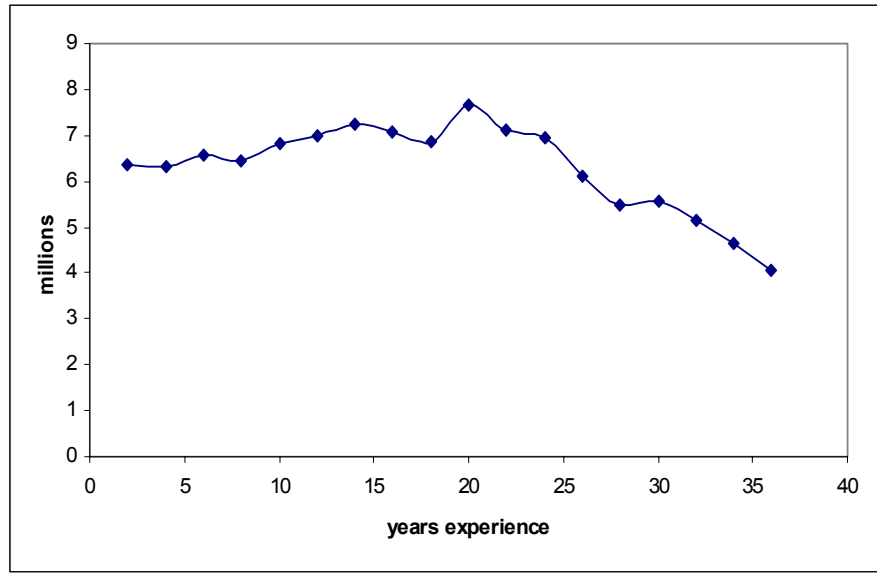
Figure 12: Sample size by years of experience

6
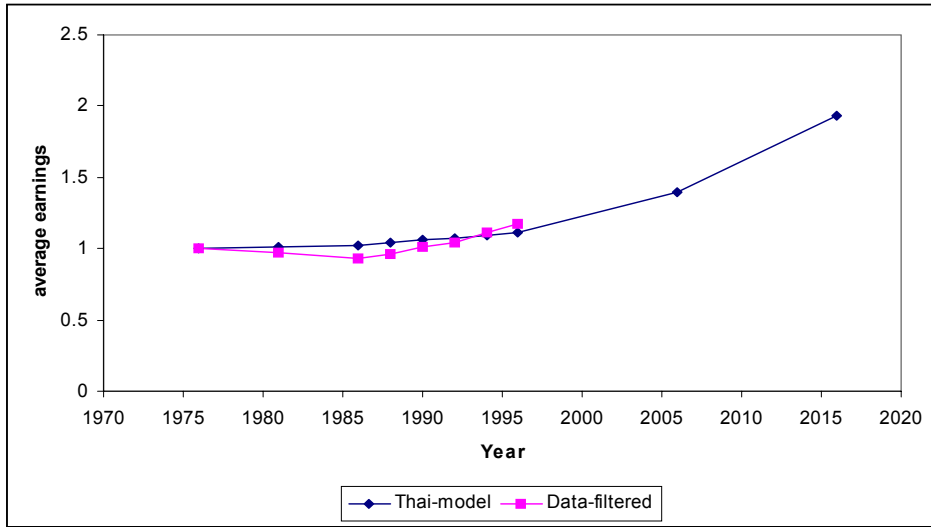
Figure 13: Average earnings time series in model and data and
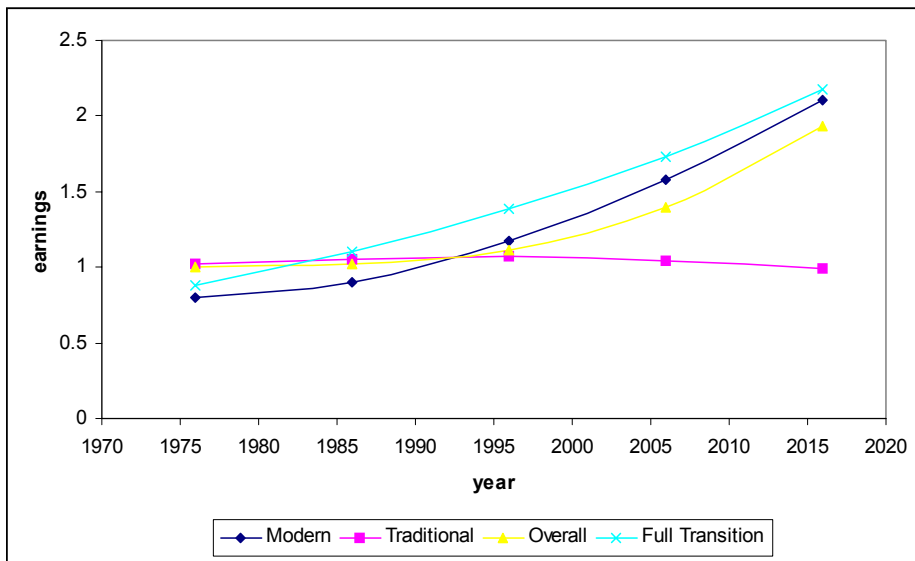
Figure 14: Earnings from model (i) across sectors, (ii) overall and (iii) in a full transition economy

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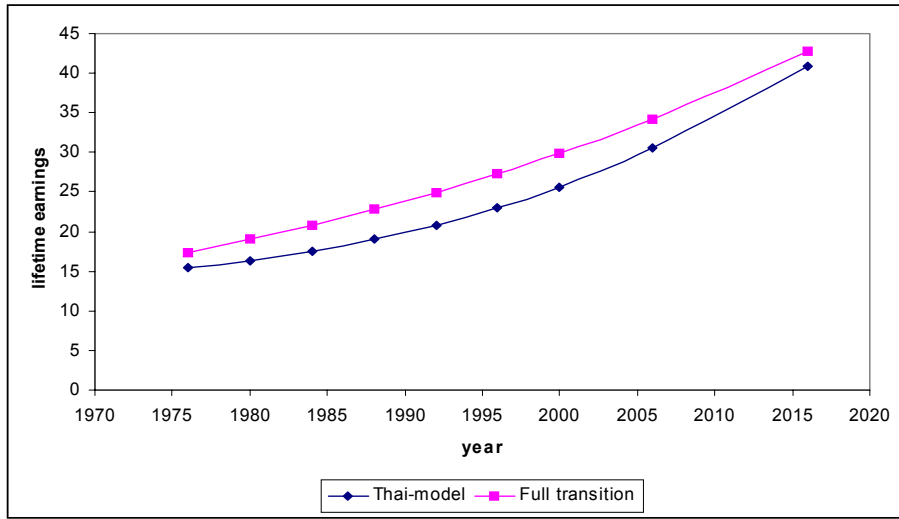
Figure 15: Lifetime earnings from model (i) overall and (ii) in a full transition economy
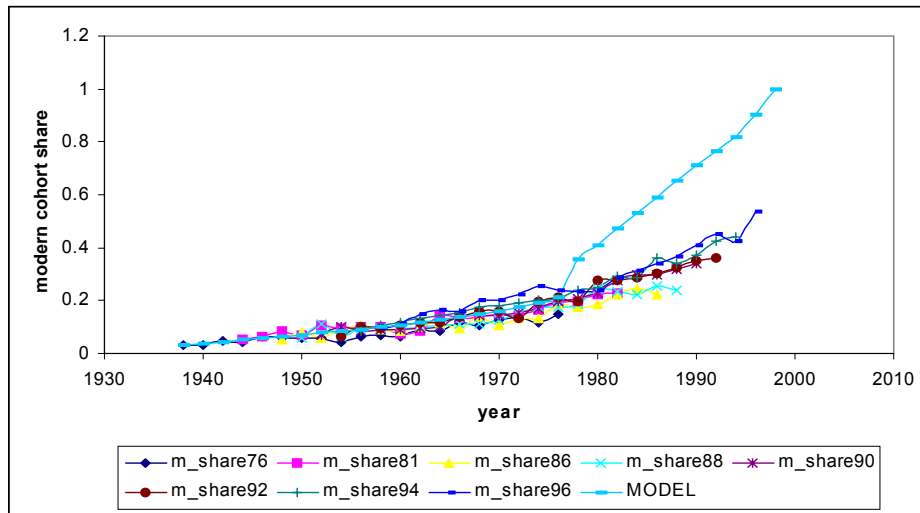
Figure 16: Modern cohort share in model and data

8
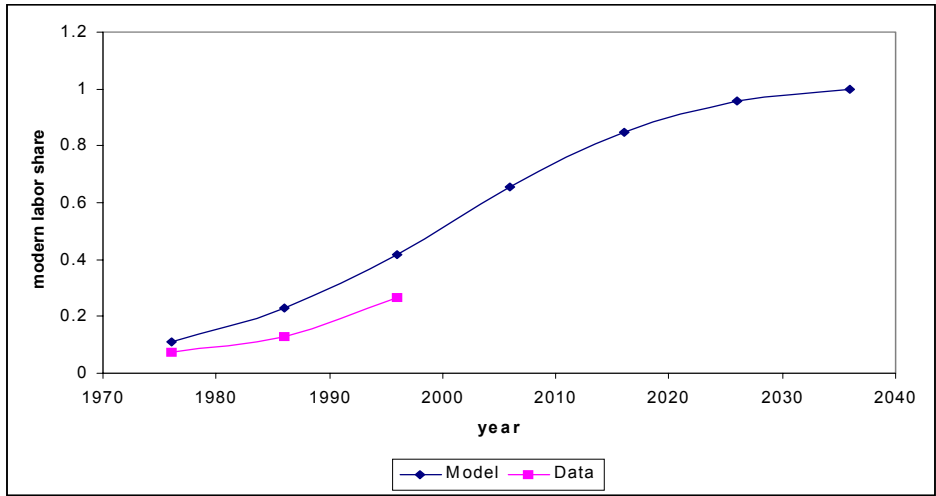
Figure 17: Modern labor share in model and data
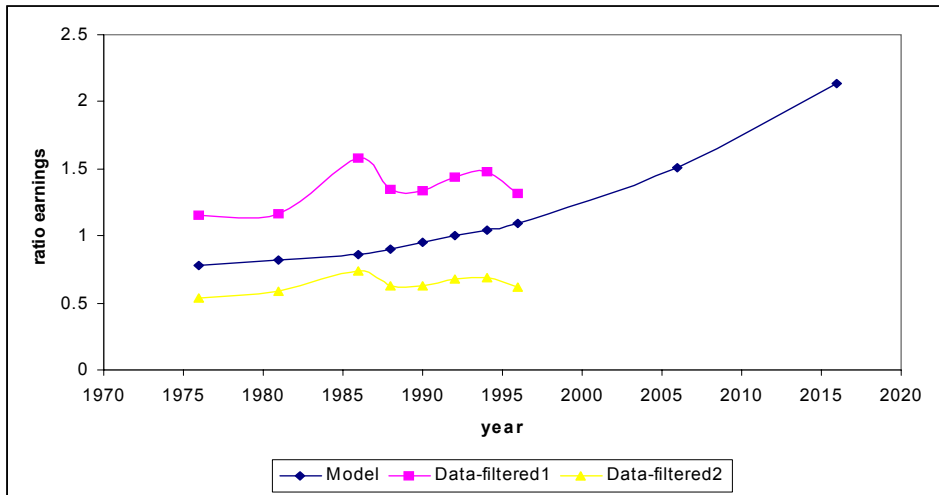
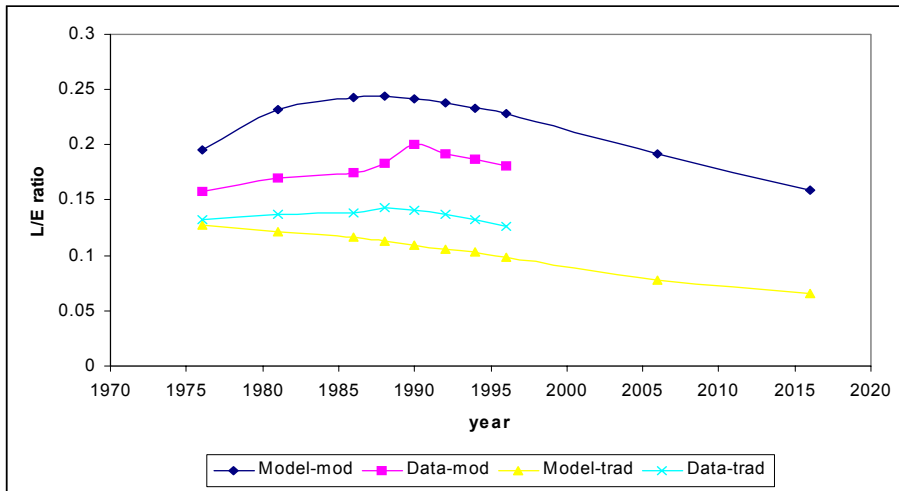Figure 18: Ratio average earnings in modern sector over traditional sector

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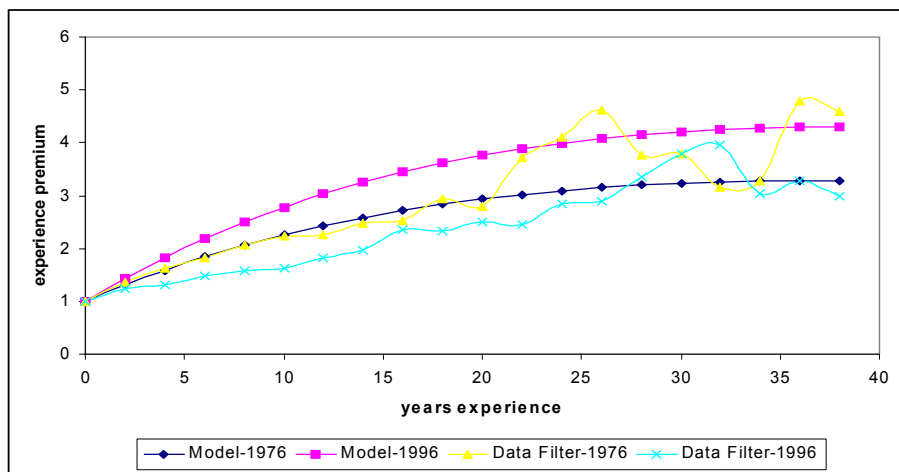Figure 19: Labor-experience ratios in the model and data for modern and traditional sectors

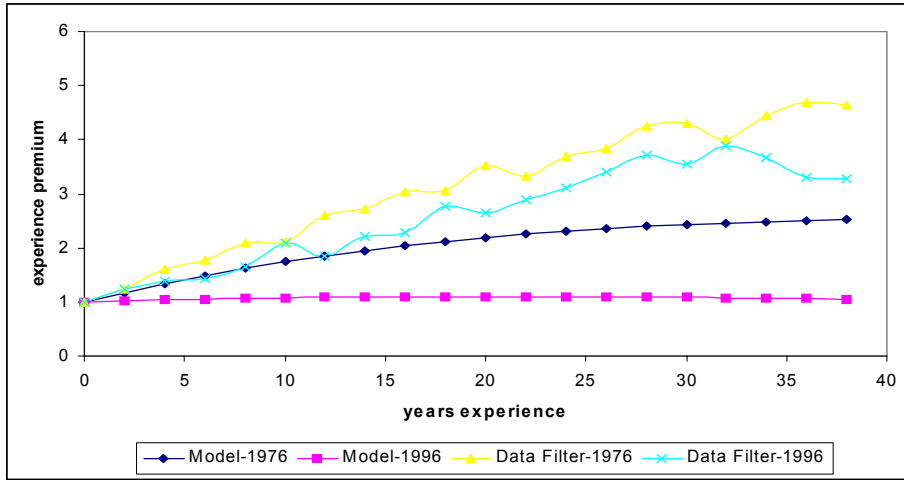Figure 20: Modern experience-earnings profile: 1976, 1996

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Figure 21: Traditional experience-earnings profile: 1976, 1996