Public Policy and Economic Growth in a Developing Economy with Labor-Market Frictions

Been-Lon Chen, Academia Sinica

Ping Wang, Vanderbilt University and NBER

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Correspondence: Ping Wang, Department of Economics, Vanderbilt University, Nashville, TN 37235, U.S.A., (Phone) 615-322-2388, (Fax) 615-343-8495, (E-mail) ping.wang@vanderbilt.edu.

1 Introduction

Following the step of the Asian giant, Japan, the four tigers, Hong Kong, Korea, Singapore and Taiwan all experienced prolonged growth over the past four decades. Over the entire period, their per capital real GDP growth rates averaged more than 6%; over some nontrivial time spans, such growth rates reached double digits. While Hong Kong and Singapore are urban economies with very specialized industries, Korea and Taiwan are more typical small open economies whose experiences may provide useful lessons to other developing countries.[1] Since our focus is on human capital and previous studies suggest that human capital is more crucial to Taiwan's advancement, we restrict our attention to the economic development in Taiwan.[2]

A central feature of the labor market in a developing economy is the presence of severe market frictions. There are substantial information and development barriers to labor search, recruiting, and job creation. Thus, the canonical Walrasian neoclassical growth framework is not well-suited for the purpose of our study. Moreover, to capture the government role of education, we also extend the standard Uzawa-Lucas model of human capital by incorporating an exogenous component of human capital accumulation independent of individual effort. This generalization allows us to compare mandatory public education and education subsidy programs in a simple fashion.

Specifically, we follow the idea developed by Diamond (1982), Mortensen (1982), Pissaridis (1984) and Laing, Palivos and Wang (1995) by postulating that both vacancy creation and job search are costly and that vacancies and job seekers are brought together by a matching technology exhibiting constant returns. Our main departure from this prototypical labor search literature is the consideration of "large" firms and households in the sense that each firm can create multiple vacancies and each household can choose search intensity endogenously, following the real-business-cycle search model developed by Merz (1995). It should be noted that Merz's paper studies how labor market frictions influence the effect of technology shocks on the business cycle in a real production economy, whereas our paper examines the

[1] For full documentation of the development experiences in Korea and Taiwan, the reader is referred to Amsden (1989) and Kuo (1983), respectively.

[2] Human capital accounts for 20% of Korean output growth, but 45% of Taiwanese output growth.

interactions of between short-run market frictions and long-run endogenous human capital accumulation. In contrast to Merz's setup where vacancy creation and job search intensity require real resources of goods, these costly activities in our framework are all in terms of labor and time allocation. This latter feature enables us to examine the long-run labor-leisure-education-search tradeoffs in the presence of labor market frictions. Our calibration exercises suggest the labor market frictions in Taiwan are nontrivial.

We further consider four public policy programs: (i) a public education policy that enhances the exogenous component of human capital growth; (ii) an education subsidy policy that raises the marginal benefit of education; (iii) a labor market coordination policy that increases the degree matching efficacy; and, (iv) an investment subsidy policy that reduces the marginal cost of vacancy creation.[3] By calibration exercises, we find that the public education policy does not change education effort or matching rates by much and hence its effects on growth and employment are essentially trivial. However, a small education subsidy can lead to a large increase in education effort, search intensity and job finding rate, and hence a large, positive effects on employment and output growth. A labor market coordination policy and an investment subsidy policy yield intermediate growth and employment effects. Therefore, we can conclude that the Taiwanese development strategy of starting at mandatory basic education but shifting to higher education after taking off may be regarded as the primary source of growth. Additionally, the workforce matching program may also play an important role in driving Taiwan's rapid and sustained growth.

2 A Tale of Taiwan's Growth Miracle

In the absence of natural resources, Taiwan must rely on outward development strategy taking full advantage of the international market. The government role in enhancing human capital accumulation and in designing market-oriented development strategies have been crucial to its industrialization process. Upon ending its colonial era under Japan and becoming a base for the nationalist government (ruled under Kuomington) to retreat 1949, Taiwan suf-

[3] The reader may also consult with Thorbecke and Wan (1999) for discussion on some successful development programs that have fostered the take-off of the Taiwanese economy.

fered a stagation with essentially zero growth and high inflation. After the monetary reform and land reform, Taiwan began its First Economic Development Plan in 1953, emphasizing savings incentives, education, export promotion and smooth transition from agricultural to manufacturing economies. By mid-1960s, the Taiwan economy took off, with per capita output growth rates jumping from 3 to 6%, net saving rates from 8 to 13%, investment ratios from 6 to 10%, and manufacturing output shares from 13 to 25%.

Over the next 3 and a half decades (1966-2001), Taiwan has enjoyed a sustained rapid growth (see Table 1). Its per capita out grew at 6.48% and employment at 2.58%. Its private and public enterprise capital grew at 13.41% and its government capital grew at 16.66%. While public enterprises filled some key but nonprofitable industries, government capital assisted in fundamental infrastructures for economic development.

Over the same period, skilled labor measured by those undertaking secondary and higher education increased rapidly at 5.27 and 8.90% respectively. Notably, Taiwan's Economic Development Plans devoted considerable attention to the improvement of labor quality. It started from a focus on reducing the illiteracy rate in the early 1950s to an overall workforce plan contracted with Stanford Research Institute to upgrade labor efficiency in 1962. In the First Manpower Development Plan incepted in 1966, it established a nine-year mandatory education system effective the academic year of 1968-69.[4] Then, there was an expansion of vocational shools to support industry needs. Moreover, there was emphasis on higher education and training of scientists, technologically-skilled engineers and business managers.

As shown in Table 2a, the literacy rate in 1954 was only 60.3%, which increased rapidly to 84.7% in 1967; by 2001, it reached 95.8%. For secondary education, only 10.9% completed at least 12 years of schooling in 1954; this figure was more than doubled, at 28% in 1969, and reached 76.7% by 2001. More dramaticlly, the proportion of population undertaking higher education (completing 15 or more years of schooling) increased from 1.6% in 1954, to 3.5% in 1969, to 6.8% in 1979, to an impressive figure of 25.2% in 2001 which is comparable to many OECD developed countries.

Table 2b reconfirms the fields concentrations as a result of the Manpower Development

[4]The nine-year mandatory education covers grade 1 through grade 9. Yet, high school education was provided essentially free (the annual tuition was less than US$15 in 1968).

plan: from academic year 1965-66 to 1975-76, there was a big leap in higher educational degrees conferred in engineering fields, from 15.1 to 30.3%. In 2000-01, higher education degrees conferred in engineering and social and natural sciences accounted for almost 3 quarters of the total. The education system helped sector shifts and industrial transformation smoothly and successfully. As shown in Table 2c, the output and employment shares of the manufacturing industry were merely 12.9 and 12.4% in 1952, rapidly increasing to 29.2 and 20.9% in 1970, and to a peak of 36.0 and 32.9% in 1980. Since then, the output and employment shares of commerce were enlarged. By 2001, the output and employment shares of manufacturing and commerce accounted about 45 and 50% of the total, while the comparable shares of the primary industry reduced to 1.9 and 7.5%.

3 The Model

Time is discrete. The basic economy features three theatres of economic activities: a continuum of identical infinitely lived competitive firms (of measure one), a continuum of identical infinitely lived households (of measure one) and a fiscal authority. All individual agents have perfect foresights. There are two productive factors: capital and labor, both owned by households. Firms and households exchange in both goods and factor markets. The goods market is Walrasian and the capital market is perfect, but the labor market exhibits search/entry frictions. While each firm can create multiple vacancies and each household can choose search intensity endogenously, both vacancy creation and search intensity are costly.

To avoid complexity involved in managing the distribution of the employed, the unemployed and their respective cash holdings, we adopt the "large households" framework proposed by Lucas (1990). Specifically, each household can be thought of containing a continuum of "members" who are employed (workers) and unemployed (job seekers or searching workers), with the sum of their mass normalized to unity. All members pool their income as well as their enjoyment of the fruit of employment (consumption) and unemployment (leisure). Vacancies and job seekers are brought together through a Diamond (1982) type matching technology, where the flow matches depends on the masses of both matching parties. Each vacancy can be filled by exactly one searching workers. At an exogenous rate, filled vacancies and workers are separated every period and separated workers immediately become job seekers.

Finally, the benevolent fiscal authority determines tax and education subsidy policies by maintaining periodic budget balance.

3.1 Firms

A representative firm, at a particular period t, rents capital k_t (beginning-of-period measure) from households at a gross rental rate r_t and employs labor n_t at a real market wage rate w_t to produce a single final good y_t under a constant-returns-to-scale Cobb-Douglas technology. Not all employed workers at the representative firm are devoted to production. A mass of workers of measure Φ are employed solely to maintain the vacancies v_t, which can be thought of covering the costs of posting vacancies, managing personnel-related documentations, as well as providing and maintaining the office space. Since such time costs are likely to exhibit scale economies, we postulate:

$$\Phi(v_t) = \phi v_t^{\varepsilon}$$

where $\varepsilon \in (0,1)$ reflects the scale economies and $\phi > 0$ captures any exogenous shift in the cost of vacancy creation and management, thereafter shortly referring to it as the vacancy creation cost. Accordingly, the measure of workers used for manufacturing is $n_t - \Phi(v_t)$ augmented by their corresponding levels of human capital h_t, and the output of the representative firm can now be specified as:

$$y_t = Ak_t^{\alpha} \left[(n_t - \Phi(v_t))\, h_t \right]^{1-\alpha}$$

where $\alpha \in (0,1)$ is the output elasticity of capital and $A > 0$ denotes the scaling factor of the production technology.

Let ψ be the (exogenous) job separation rate and η_t be the (endogenous) employee recruitment rate at which a firm locates a searching worker. Since each vacancy can be filled by only one worker, the inflow of workers to employment is $\eta_t v_t$ and the outflow is ψn_t. Employment within the representative firm thus evolves according to the following birth-death process: $n_{t+1} - n_t = \eta_t v_t - \psi n_t$, or, by rearranging terms:

$$n_{t+1} = (1-\psi)n_t + \eta_t v_t \tag{1}$$

Therefore, under constraint (1), the representative firm will, facing the state n_t, choose vacancies and capital demand (v_t, k_t) to maximize its value, $\Gamma(n_t)$, which is the sum of the discounted real profit flows or residual consumption, $q_t = y_t - w_t n_t h_t - r_t k_t$. That is, firms are treated as residual claimers as in Diamond and Yellin (1990). Applying the standard dynamic programming techniques, we can express the representative firm's optimization problem in Bellman equation form as:

$$\Gamma(n_t) = \max_{v_t,\, k_t} \left\{ A k_t^{\alpha} \left[(n_t - \Phi(v_t))\, h_t \right]^{1-\alpha} - w_t n_t h_t - r_t k_t \right\} + \frac{1}{1+r} \Gamma(n_{t+1}) \tag{2}$$

subject to constraint (1).

3.2 Households

Facing a pooled resource, the representative "large" household has a unified preference capturing enjoyment of all its members: the employed, whose fraction is n_t, and the unemployed, whose fraction is $1 - n_t - e_t$, where e_t is the fraction devoted to education (or, human capital accumulation). Members of the representative household value both consumption, c_t, and leisure, $(1 - s_t)(1 - n_t - e_t)$, where s_t denotes the representative household's search intensity in unit of time (i.e., it is the fraction of time spent by unemployed members on job search). Under this framework, it is obvious that not all unemployed time can be regarded as leisure, because search intensity takes away such an enjoyment. Accordingly, the representative household's preference can be written in a standard time-additive form as:

$$\Omega = \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho} \right)^t U\left(c_t, (1 - s_t)(1 - n_t - e_t)\right)$$

where Ω is the lifetime utility, $\rho > 0$ is the subjective rate of time preference, and, the felicity function, U, is strictly increasing in both arguments, strictly concave in consumption and concave in leisure.

Since the household owns capital k_t, its budget constraint must include capital investment and the associated costs. Let $\delta \in (0, 1)$ denote the constant rate of capital depreciation. Given the market rental and wage rates (r_t, w_t), consumption and gross capital investment $(k_{t+1} - k_t + \delta k_t)$ can be supported by wage and rental income:

$$k_{t+1} = (1 - \delta + r_t) k_t + w_t n_t h_t - c_t \tag{3}$$

Denote the exogenous component of the human capital accumulation rate as ζ, which captures public education promotion as well as intergenerational and peer spillovers. We can thus extend Lucas (1988) to specify the human capital evolution equation as:

$$\frac{h_{t+1} - h_t}{h_t} = \zeta + De_t \tag{4}$$

where $D > 0$ measures the maximum rate of endogenous human capital accumulation.

Denote by μ_t the (endogenous) job finding rate at which a searching worker seeks for a job vacancy. Recall that each vacancy can be filled by only one worker, so the inflow of workers to employment $\mu_t s_t(1 - n_t - e_t)$ net of the outflow ψn_t must be equal to incremental employment. Thus, similar to those specified in the firms decision above, employment in the household perspective evolves according to:

$$n_{t+1} = (1 - \psi)n_t + \mu_t s_t(1 - n_t - e_t) \tag{5}$$

The representative household's optimization problem in Bellman equation form can therefore be specified as:

$$\Omega(k_t, h_t, n_t) = \max_{c_t,\, e_t,\, s_t} U\left(c_t, (1 - s_t)(1 - n_t - e_t)h_t\right) + \frac{1}{1+\rho}\Omega(k_{t+1}, h_{t+1}, n_{t+1}) \tag{6}$$

subject to constraints (5) and (4).

3.3 The Aggregate Economy

Because there is only a single good in the economy, the resource constraint requires that aggregate goods supply must be equal to aggregate goods demand, which is the sum of households' consumption and gross investment as well as firms' residual consumption:

$$x_t + [k_{t+1} - (1 - \delta)k_t] = Ak_t^{\alpha}\left[\left(n_t - \Phi\left(v_t\right)\right)h_t\right]^{1-\alpha} \tag{7}$$

where $x_t \equiv c_t + q_t$ measures the aggregate consumption of the economy.

While the capital market is perfect as in the conventional Walrasian models, the labor market exhibit search frictions. Given the job separation rate ψ and the aggregate flow matches M_t, aggregate employment evolves according to the following birth-death process:

$$N_{t+1} = (1 - \psi)N_t + M_t \tag{8}$$

Similar to Diamond (1982), the aggregate flow matches depend on the masses of both matching parties, namely, search intensity augmented job seekers, $s_t(1 - N_t - E_t)$, and vacancies, V_t. Assume the matching technology exhibits constant-returns-to-scale property, as suggested by the empirical evidence in Blanchard and Diamond (1990) using the U.S. data. We can specify:

$$M_t = B\left[s_t(1 - N_t - E_t)\right]^{\beta} V_t^{1-\beta} \tag{9}$$

where $B > 0$ measures the degree of matching efficacy and $\beta \in (0, 1)$.

Since each vacancy can be filled by exactly one searching workers, the tightness of the labor market to firms, denoted θ_t, can be measured by the ratio of vacancies to searching workers:

$$\theta_t \equiv \frac{V_t}{1 - N_t - E_t} \tag{10}$$

We can then rewrite the aggregate flow matches in terms the current employment, the search intensity and the tightness of labor market to firms:

$$M_t = B(1 - N_t - E_t)s_t^{\beta}\theta_t^{1-\beta} \tag{11}$$

Using (11) and (10), we can express the employee recruitment rate (η_t) and the job finding rate (μ_t) as:

$$\eta_t = \frac{M_t}{V_t} = B\left(\frac{\theta_t}{s_t}\right)^{-\beta} \tag{12}$$

$$\mu_t = \frac{M_t}{s_t(1 - N_t - E_t)} = B\left(\frac{\theta_t}{s_t}\right)^{1-\beta} \tag{13}$$

Thus, the tighter the labor market is to firms, the lower the employee recruitment rate and the higher the job finding rate are. An increase in job seekers' search intensity crowds out job seeking opportunities and hence reduces the average job finding rate, although it eases firms' recruiting process by raising their employee recruitment rate.

Recall that all firms and households are identical. By symmetry, we have: $N_t = n_t$, $E_t = e_t$, and $V_t = v_t$. Finally, simple Nash bargaining rule determines the distribution of net output:

$$q_t = zw_t n_t h_t \tag{14}$$

where $\frac{1}{1+z}$ and $\frac{z}{1+z}$ measure the shares of surplus accrued to workers and firm owners, respectively. The special case with $z = 0$ corresponds to a simple symmetric Nash bargaining rule.

4 Optimization and Equilibrium

In this section, we first derive the optimizing conditions for a representative firm and a representative household. We then define a balanced growth analysis and illustrate how to determine the balanced growth values of the key macroeconomic variables such as employment, output, capital as well as the variables related to search such as probabilities of job matching, search intensity and vacancy rate.

4.1 Optimizing Conditions for a Representative Firm

Since the representative firm rents capital from households, it faces only one evolution equation on the state variable n. To derive optimizing conditions for the firm, we substitute the evolution equations into the firm's next-period value function to obtain:

$$\begin{aligned}\Gamma(n) &= \max_{v,\,k} \left[Ak^{\alpha}\left[(n-\Phi(v))\,h\right]^{1-\alpha} - wnh - rk\right] \\ &\quad + \frac{1}{1+r}\Gamma\left((1-\psi)n + \eta v\right)\end{aligned}$$

The firm decides on (i) how many vacancies to create (v) and (ii) how much capital to rent and utilize in producing the final good (k). Let n' denote the state in the next period. Since this is a recursive problem with only the two adjacent periods relevant for optimization, the subscript t is no longer necessary and hence dropped.

The first-order conditions with respect to vacancy creation and capital demand are given by,

$$\frac{\eta}{1+r}\Gamma_1\left(n'\right) = (1-\alpha)\Phi'(v)Ak^{\alpha}\left(n-\Phi(v)\right)^{-\alpha}h^{1-\alpha} \tag{15}$$

$$\alpha A\left(\frac{k}{h}\right)^{\alpha-1}\left(n-\Phi(v)\right)^{1-\alpha} = r \tag{16}$$

Equation (15) states that at the margin, the benefit from creating additional vacancy in order to make new hires should equal the cost in terms of staff-time necessary to make these vacancies available to the searching workers. Equation (16) is the standard capital demand equation, stating the equalization of its marginal product to its rental cost. The optimality also requires the Benveniste-Scheinkman condition to hold, which can be simplified as follows by making use of the first order conditions above:

$$\Gamma_1(n) = \left[1 + \frac{\Phi'(v)\,(1-\psi)}{\eta}\right](1-\alpha)Ak^{\alpha}\,(n - \Phi\,(v))^{-\alpha}\,h^{1-\alpha} - wh \tag{17}$$

4.2 Optimizing Conditions for a Representative Household

The constraints for the household consist of the laws of motion for three state variables (k, h, n), given by (3), (4) and (5). Substituting the evolution equations into the household's next-period value function, we obtain:

$$\begin{aligned}\Omega(k,h,n) &= \max_{c,\,e,\,s} U\,(c,(1-s)(1-n-e)) \\ &+ \frac{1}{1+\rho}\Omega\,((1-\delta+r)k + wnh - c, (1+\zeta+De)h, (1-\psi)n + \mu s(1-n-e))\end{aligned}$$

Let $\mathcal{H}$ denote the vector of state variables this period, namely, $\mathcal{H} \equiv (k, h, n)$, and $\mathcal{H}'$ denote the triplets in the next period. The first-order conditions with respect to consumption demand, time devoted to education and search intensity can be derived as:

$$U_1\,(c,(1-s)(1-n)) = \frac{1}{1+\rho}\Omega_1(\mathcal{H}') \tag{18}$$

$$\frac{1}{1+\rho}\left[Dh\Omega_2(\mathcal{H}') - \mu s\Omega_3(\mathcal{H}')\right] = U_2\,(c,(1-s)(1-n-e)) \tag{19}$$

$$\frac{\mu}{1+\rho}\Omega_3(\mathcal{H}') = U_2\,(c,(1-s)(1-n-e)) \tag{20}$$

Equation (18) is stardard, whereas equation (19) requires the future net gain from undertaking education, which is the gain from productivity net of the loss of employment, equals the current loss from a reduction in leisure. Equation (20) states that the employment gain next period from a marginal increase in search intensity this period equals the disutility from the corresponding reduction in leisure.

The Benveniste-Scheinkman conditions governing the states (k, h, n) are given as follows after making use of the first order conditions above:

$$\Omega_1(\mathcal{H}) = \frac{1-\delta+r}{1+\rho}\Omega_1(\mathcal{H}') \tag{21}$$

$$\Omega_2(\mathcal{H}) = \frac{wn}{1+\rho}\Omega_1(\mathcal{H}') + \frac{1+\zeta+De}{1+\rho}\Omega_2(\mathcal{H}') \tag{22}$$

$$\Omega_3(\mathcal{H}) = -(1-s)U_2\left(c,(1-s)(1-n-e)\right) + \frac{wh}{1+\rho}\Omega_1(\mathcal{H}') + \frac{1-\psi-\mu s}{1+\rho}\Omega_3(\mathcal{H}') \tag{23}$$

4.3 Balanced Growth Conditions

The model economy exhibits perpetual growth and hence we cannot simply analyze the economic aggregates without transforming perpetually growing quantities into stationary ratios. Throughout the remainder of the paper, we focus on a *balanced growth path* (BGP) along which consumption, physical and human capital, and output all grow at positive constant rates. Since the production function is homogeneous of degree one in reproducible factors (k and h) and the human capital accumulation equation is linear (in h), these quantities (c, Z, k, h and y) must all grow at a common rate, g, on a BGP, whereas other quantities are all constant. For analytical convenience, we focus on a benchmark case where the felicity function U takes the Hansen-Rogerson separable form previously used by Benhabib and Perli (1994):

$$U\left(c_t,(1-s_t)(1-n_t-e_t)h_t\right) = \ln c_t + \Lambda\left((1-s_t)(1-n_t-e_t)\right)$$

where $\Lambda_1 > 0$ and $\Lambda_{11} \leq 0$.[5] Moreover, we consider a simple case where firms' residual consumption in effective units, $z \equiv Z/h$, is taken as given.[6]

Substituting properly dated equation (15) into (17) and using the common growth property imply the following labor demand relationship:

$$w = (1-\alpha)A\left(\frac{k}{h}\right)^{\alpha}\left(n-\Phi(v)\right)^{-\alpha}(1-\Upsilon) \tag{24}$$

where $\Upsilon \equiv \frac{\Phi'(v)}{\eta}\left(\psi + \frac{r-g}{1+g}\right)$ measures the wage discount, i.e., the degree to which wages fall below marginal products.

[5] An alternative utility function specification is to take the transformed Cobb-Douglas form, $U = \left(\left\{c_t^{\epsilon}\left[(1-s_t)(1-n_t-e_t)h_t\right]^{1-\epsilon}\right\}^{1-\sigma} - 1\right)/(1-\sigma)$, with $\epsilon \in (0,1)$ and $\sigma > 0$.

[6] One could allow the split of the matching surplus between firms and households to be determined by a Nash bargain, which would however lead to greater complexity without adding much additional insights. We therefore consider a fixed sharing rule, where $z = 0$ may be regarded as the extreme case that firms have no bargaining power (a zero profit solution).

Along a BGP, we can rewrite the two evolution equations, (3) and (4), as:

$$\frac{c}{h} = [r - (\delta + g)]\,\frac{k}{h} + wn \tag{25}$$

$$e = \frac{g - \zeta}{D} \tag{26}$$

From (18), (19) and (20), we can derive: $\Omega_1(\mathcal{H}') = (1+\rho)/c = \Omega_1(\mathcal{H})/(1+g)$, $\Omega_2(\mathcal{H}') = \Lambda_1(1+\rho)(1+s)/(Dh) = \Omega_2(\mathcal{H})/(1+g)$, and $\Omega_3(\mathcal{H}') = \Lambda_1(1+\rho)/\mu = \Omega_3(\mathcal{H})$. These together with (26) can be substituted into (21), (22) and (23) to obtain:

$$g = \frac{r - (\delta + \rho)}{1+\rho} \tag{27}$$

$$\rho(1+g)(1+s)\Lambda_1 = Dn\frac{wh}{c}$$

$$\left(1 + \frac{\rho+\psi}{\mu}\right)\Lambda_1\left((1-s)(1-n-\frac{g-\zeta}{D})\right) = \frac{w}{c/h} \tag{28}$$

Combining the last two expressions generates:

$$\rho(1+g)(1+s) = Dn\left(1 + \frac{\rho+\psi}{\mu}\right) \tag{29}$$

Equation (27) is the Keynes-Ramsey equation within the endogenous growth framework. While (28) displays the labor-leisure trade-off that identifies the labor supply schedule, (29) governs the trade-off between education and search.

The steady-state matching (Beveridge curve) relationships give:

$$\psi n = \mu s(1-n-e) = \eta v = B\left[s(1-n-e)\right]^{\beta} v^{1-\beta} \tag{30}$$

Under (14), the resource constraint can also be rewritten as,

$$\frac{c}{h} + (\delta+g)\frac{k}{h} = A\left(\frac{k}{h}\right)^{\alpha}(n - \Phi(v))^{1-\alpha} - zwn \tag{31}$$

By the linear homogeneity property of the production function, the zero profit condition must satisfy and one of the budget constraint (25), the resource constraint (31) and the zero profit condition must be redundant (i.e., the Walras' law is met). Combining (25) and (31) yields the equilibrium wage in effective unit (wn),

$$wn = \frac{1}{1+z}\left[A\left(\frac{k}{h}\right)^{\alpha}(n-\Phi(v))^{1-\alpha} - r\left(\frac{k}{h}\right)\right] \tag{32}$$

Thus, our system constitutes 11 equations, (16), (24)-(30) and (32), which can be used to solve the BGP values of $\{g, \frac{c}{h}, \frac{k}{h}, n, e, s, v, \mu, \eta, r, w\}$.

5 Characterizing the Balanced Growth Equilibrium

We begin by analyzing as much as possible the balanced growth equilibrium analytically.

5.1 Comparative Static Analysis

The equations determining the steady state can be re-arranged in a recursive fashion that is conducive to perform comparative statics. Essentially, we could obtain two equations determining μ and N. The rest of variables can then be derived accordingly.

To see this, we use (26) and (30) to derive:

$$s = \frac{\psi n}{(1 - n - \frac{g-\zeta}{D})\mu} \tag{33}$$

$$\eta = B^{\frac{1}{1-\beta}} \mu^{\frac{=\beta}{1-\beta}} = \eta(\mu) \tag{34}$$

$$v = B^{\frac{-1}{1-\beta}} \mu^{\frac{\beta}{1-\beta}} \psi n = v(\mu, n) \tag{35}$$

where it is clear that $\eta_\mu < 0$, $v_\mu > 0$ and $v_n > 0$. To guarantee nonnegativity of search intensity, we impose:

Condition S: $\zeta + D(1-n) > g$.

From (16), we can solve:

$$\frac{k}{h} = \left(\frac{\alpha A}{r}\right)^{\frac{1}{1-\alpha}} (n - \Phi(v)) = \kappa(\mu, n) \tag{36}$$

where $\kappa_\mu < 0$ and $\kappa_n > 0$. Moreover, it is not difficult to show that both $r\frac{k}{h}$ and $r\frac{k/h}{n}$ are decreasing in μ and increasing in n as well. Also, we can write the effective capital-labor ratio as: $\chi \equiv \frac{k/h}{n-\Phi(v)} = \left(\frac{\alpha A}{r}\right)^{\frac{1}{1-\alpha}}$. Substituting (33) into (29), we get the modified Keynes-Ramsey equation in our endogenous growth economy:

$$\rho + \psi + \mu = \rho(1+g)\left[\frac{\mu}{Dn} + \frac{\psi}{D(1-n) + \zeta - g}\right] \tag{37}$$

or,

$$g = g(\mu, n; D, \zeta) \tag{38}$$

where $g_\mu < 0$, $g_n \lesseqgtr 0$, $g_D > 0$ and.$g_\zeta > 0$. The ambiguity of the effect of n on g is due to the presence of a positive direct effect and a negative indirect effect via search effort. For the remainder of the analytic discussion, we restrict our attention to the case where the direct effect dominates so that $g_n > 0$.

We next plug (38) into (27) and (29) to derive:

$$r = (\delta + \rho) + (1 + \rho)g = r(\mu, n) \tag{39}$$

$$s = \frac{\psi n}{(1 - n - \frac{g-\zeta}{D})\mu} = s(\mu, n; D, \zeta) \tag{40}$$

where $r_\mu < 0$, $r_n > 0$, $s_\mu < 0$, $s_n > 0$, $s_D < 0$ and $s_\zeta < 0$. Substituting (34), (35) and (38) into the wage discount expression yields:

$$\Upsilon = \Upsilon(\mu, n; B) \tag{41}$$

where $\Upsilon_\mu \lesseqgtr 0$ and $\Upsilon_n < 0$ and $\Upsilon_B < 0$. While higher labor employment is associated with higher growth and hence lower discount, the job finding rate generates two opposing effects. On the one hand, it lowers growth and raises wage discount; on the other, it induces job vacancies and thus reduces wage discount. Additionally, the better the labor market matching environment is (higher B), the smaller the wage discount will be.

Substituting (36) and (39) into (32) implies:

$$w = \frac{1}{1+z}\frac{1-\alpha}{\alpha}\frac{r(\mu, n)}{n}\kappa(\mu, n) = w(\mu, n) \tag{42}$$

where using (41), one can show $w_\mu \lesseqgtr 0$ and $w_n > 0$.From (25) and (32), one obtains:

$$\frac{c}{h} = \frac{1}{1-\alpha}\left[\left(1 - \alpha\frac{\delta + g(\mu, n)}{r(\mu, n)}\right) + \alpha z\left(1 - \frac{\delta + g(\mu, n)}{r(\mu, n)}\right)\right] w(\mu, n)n \tag{43}$$

Consider the case with $\Lambda_{11} = 0$.[7] Substituting (43) into (28) and utilizing (24), (36) and (41), we can derive the following equilibrium labor locus:

$$\begin{aligned}(1-\alpha) - \left(1 + \frac{\rho + \psi}{\mu}\right)\Lambda_1\left(1 - \alpha\frac{\delta + g(\mu, n)}{r(\mu, n)}\right)n \\ = \alpha z\left(1 + \frac{\rho + \psi}{\mu}\right)\Lambda_1\left(1 - \frac{\delta + g(\mu, n)}{r(\mu, n)}\right)n\end{aligned} \tag{44}$$

[7] This assumption is innocuous - our main conclusions would not depend on this though the algebra is greatly simplified.

5.2 Numerical Analysis

Just how severe the degree of labor market frictions is in Taiwan? We now turn to calibration exercises to quantify market tightness, search intensity, vanancy creation and wage discount.

We summarize the values of key endogenous variables and parameters in Table 3. First, we use the Taiwan data to compute the values of some observables (source: *Taiwan Statistical Data Book*, various years, Council for Economic Planning and Development, Republic of China). In particular, $g = 0.0648$ is the average per capita real GDP growth rate and $c/y = 0.73$ is the average real consumption-real GDP ratio in 1966-2001. Labor effort $n = 0.13$ is based on 50%, labor force participation rate, 44 working hours (5 and a half days) per week and on average 20 days of holidays per year in 1966-2001, and education effort $e = 0.12$ is based on 7.2 average years of schooling for ages 6-65 in 1976-2001. The real capital-real GDP ratio, $k/y = 2.1$.

In the absence of detailed data on the job finding and employee recruitment rates, we set the coefficient of matching efficicacy B to 0.25 so that the rates are within acceptable ranges (μ and η, respectively, are 0.242795 and 0.254922 in the benchmark case). In line with the growth literature, the time preference rate is set at $\rho = 0.03$. To be consistent the balanced growth equilibrium, this requires the capital depreciation rate be at: $\delta = 0.063771$, with a capital rental rate of 16.0540% and a capital income share of $\alpha = 0.337082$. In line with the labor search literature, we set parameter values $\beta = 0.4$ and $\epsilon = 0.5$. By normalizing $A = 1$ and $z = 1$ (symmetric Nash bargaining rule), we next calibrate $\phi = 0.286414$, $\psi = 0.02$, $\Lambda_1 = 5.304929$ and $\zeta = 0.04$ so that g, e, n and c/y fit the observed data reported above. The imputed value of D is then 0.206667. The values for other endogenous variables, v, s, w, Υ and Φ can then be computed accordingly. Table 3 summarizes the relevant parameter and calibrated values.

Thus, in an environment mimicking the Taiwanese economy, severe labor market frictions are present underlying the surface of rapid output growth. About 1.4% of labor time is devoted to search, or equivalently, about 11% of of the total labor hours. Vacancy creation requires about 0.3% of total labor costs, whereas the wage discount exceeds 60%. While both job finding and employment recruitment rates are about 1/4, job separation is at a rate of

2%.

6 Public Policy

In this simple model economy, we may consider four public policy programs of particular interest: (i) a public education policy that enhances the exogenous component of human capital growth (ζ); (ii) an education subsidy policy that raises the marginal benefit of education (D); (iii) a labor market coordination policy that increases the degree matching efficacy (B); and, (iv) an investment subsidy policy that reduces the marginal cost of vacancy creation (ϕ). Table 4 summarizes the result of some key endogenous variables in response to 1% favorable changes in each of the four policies. For the sake of simplicity, we assume that these policy can be implemented by a nondistortionary tax. This is not too much off, as in the 1960s and 1970s, the average distortionary labor and capital income tax rates in Taiwan were extremely low (3.9 and 13.3%, respectively).[8]

As one can see, the public education policy does not change education effort or matching rates by much. As a consequence, its effects on growth and employment are essentially trivial. On the contrary, a small education subsidy can lead to a large increase in education effort, search intensity and job finding rate. Its effects on growth and employment are quite large. Furthermore, a labor market coordination policy and an investment subsidy policy provides intermediate growth and employment effects.

Intuitively, a public education policy that enhances the exogenous component of human capital growth (ζ) result in a positive growth effect together with a greater job finding rate, via intertemporal consumption-saving choice governed by the modified Keynes-Ramsey equation. Through labor matching, the mass of the unemployed ($1 - n - e$) must reduce, thus raising employment (n) and education effort (e). That is, despite the absence direct effect on the intensive margin, this policy enhances employment and output growth due to positive intertemporal and labor matching effects.

Concerning an education subsidy policy that raises the marginal benefit of education

[8]Sales and land/housing taxes, custom duties and monopoly revenues are the major sources of government budget inflows.

(D), we still have the above-mentioned positive intertemporal and labor matching effects. In addition, there is a direct incentive effect encouraging education effort as well as search intensity. Both leading to greater employment and higher growth. The presence of this direct incentive effect explains why it generates a large, positive growth effect.

A labor market coordination policy that increases the degree matching efficacy (B), via the Beveridge curve relationship, increases both job finding and employee recruitment rate (higher μ and η). On the one hand, the mass of the unemployed ($1 - n - e$) is lower and hence employment (n) and education effort (e) become higher. On the other hand, the mass of vacancies reduces, as does the wage discount. The latter encourages greater education and work effort. Both labor matching and wage discount effects reinforce each other, leading to higher growth.

Turning now to an investment subsidy policy that reduces the marginal cost of vacancy creation (ϕ), we have an induced increase in vacancies created as well as a lower wage discount. The former generates a positive labor matching effect, which, in conjunction with the latter wage discount effect, raises both employment and output growth.

Finally, we want to note that all four policy programs have been implemented in the process of Taiwan's economic development. Yet, the strategy of starting at mandatory basic education (basically related to ζ) and shifting to higher education (more related to D) should be highlighted as a primary source of growth. Another has to do with the workforce matching program (related to B), which also plays an important role in driving its rapid and sustained growth.

6.1 Industrial Transformation

In our stylized model, we have a single final good sector. To understand the process of industrial transformation from primary to industrial sectors, we must consider a more general setup.

The theory of economic take-off and industrial transformation is developed by Lewis (1955), Rostow (1960), Rosenstein-Rodan (1961) and Tsiang (1964). Recent contributions, including Murphy, Shleifer and Vishny (1989), Matsuyama (1991) and Chen and Shimomura (1998), emphasize that in the presence of multiple equilibria, a big push may enable industrialization, moving from a low to a high-income equilibrium. In this subsection, we restrict our attention exclusively to resource allocation, which to our belief is the key to a success development process.

In Easterly (2001), many examples of failed aid programs are provided, including Akosombo Dam in Ghana, Morogoro Shoe Factory in Tanzania and the two billion dollars U.S. Aid to Zambia. On the contrary, many successful development programs have been documented throughout the process of Taiwan's economic advancement. What accounts for such differences?

At the early stage of economic development, low level of technology and labor skills permit production of only traditional goods. Since traditional goods, rather than modern sector products, are essential for survival, comparative advantage suggests that the modern sector may be non-operative even when technology adoption is possible and labor quality is improved.[9] The activation of a modern sector requires not only resources of investment funding, skilled labor and new technology, but also appropriate matching between capital and labor, as well as industrial coordination to overcome the scale barrier. Once over the scale threshold, the modern sector can become operative and industrial transformation takes place. Human capital plays a key role, from operating profitable plants, to adopting existing technology and developing new technology, to coordinating and smoothening the industrial transformation process.

6.2 Trade

One may easily argue that trade plays an important role in a heavily trade-dependent small economy like Taiwan. Rather than going over various channels through which trade influences economic development, we would like to focus on one aspect, namely, trade liberalization. This is particularly important if one contrasts the East Asian experiences with the Latin American experiences.

Since three decades ago, Balassa (1972) has observed that the economic take offs in Taiwan and Korea in the mid 1960s feature a rapid transformation from import substitution to non-

[9] See a formal model developed by Wang and Xie (2003).

traditional exportables.[10] In fact, in the pre-liberalization stage, both economies imposed high effective protective rates (about 100%) to ensure competitiveness of domestic producers of import substitution sectors. By the mid 1960s, however, the effective protective rates were only about 50-60% in these economies. On the contrary, the comparable figures in Argentina and Brazil were 160% and 120%, respectively. Morawetz (1981) argues the overly protective import substitution policy has inhibited Columbia's long-run competitiveness in international markets.

Can the trade liberalization policy captured by a sharp drop in tariffs and a continual removal of heavy trade barriers promote economic growth? Stokey (1991) and Young (1991) provide a negative answer. Briefly speaking, under free trade, comparative advantage encourages less developed countries to produce low quality and less sophiscated goods. When human capital is accumulated via learning by producing high quality goods, free trade slows down this process and hence retards economic growth in less developed countries. Are we ready to take this conventional view as granted? Simply not. We emphasize that free trade helps both learning from exporting (cf. Bond, Jones and Wang 2003) and reverse engineering (cf. Rivera-Batiz and Romer 1991). In particular, the take-off in the modern export sector can be driven by cheap labor that can be used to produce goods for export. Under tariff protection, wages are initially high and entry into these sectors is unlikely to occur. Therefore, trade liberalization that lowers labor costs enables activation of the modern sector. This further enhances learning from exporting and reverse engineering, thereby speeding up the development process. It may be noted in an economy like Taiwan with scarce natural resources, the shortage of specific factors used in traditional exporting sectors results in lower wages, thus making its modern goods production more competitive on world markets.

7 Concluding Remarks

In our model, we have focused on labor-leisure-education-search trade-offs in the presence of labor market frictions. Accordingly, we have been abstracting any pecuniary costs associated with job search and vacancy creation. Our model may be generalized to include such costs.

[10] Recently, Adelman (1999) reconfirms this early view.

In doing so, one may mimic better the real world and conduct calibration analysis matching better with the observed rates of job turnover and unemployment following Merz (1995). Moreover, the present analysis is abstracting from an explicit government budget constraint. Just how government educational policy is executed and financed may induce a number of general equilibirum effects.

Another simplifying assumption is the Cobb-Douglas utility function specification. Should the utility function be nonhomothetic (in consumption and search-intensity augmented effective leisure), the employment rate may affect the marginal rate of substitution and the marginal product of labor differently and hence the severity of labor market frictions may have greater long-run effect on individual optimizing behavior. This extension may thus provide a plausible explanation for the short-run shocks to generate persistent movements over the business cycle.

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Table 1
Summary statistics of elements of growth for Taiwan, 1966-2001

Variable	Mean growth rate (%)	Variance	Standard error of the mean
Output	6.48	10.08	3.27
Employment	2.58	3.05	1.75
Capital (private and public enterprise)	13.41	411.10	20.28
Labor skill (education)			
Higher	8.90	97.20	9.86
Secondary	5.27	53.26	7.30
Primary	-0.71	114.35	10.69
Literacy rate	0.62	0.94	0.97
Export ratio	0.61	23.75	4.87
Government consumption	12.55	57.91	7.61
Government capital	16.66	212.06	14.56
Birth rate	-2.62	39.16	6.26
Money to output ratio	4.11	107.33	10.36

Table 2a

Educational attainment as percent of population over 6 years old

Year	Literacy	Years of schooling completed		
		6 or more	12 or more	15 or more
1954	60.3	56.4	10.9	1.6
1959	71.1	66.8	13.5	1.8
1964	77.6	73.6	17.6	2.3
1969	84.7	80.9	28.0	3.5
1974	86.7	83.8	33.9	4.8
1979	89.3	86.6	42.6	6.8
1984	91.2	89.0	49.6	8.7
1989	92.9	91.7	55.4	10.5
1994	94.2	93.3	62.7	10.1
1997	95.5	94.8	60.2	13.6
2001	95.8*	95.1*	76.7*	25.2*

*as percent of population over 15 years old

Table 2b

Higher educational degrees conferred in three general fields as a percent of total

Period	Social sciences	Natural sciences	Engineering
1965-66	38.4	6.5	15.1
1975-76	31.8	4.8	30.3
1985-86	30.3	6.3	35.3
1989-90	30.5	6.9	35.9
1995-96	31.4	9.2	33.1
2000-01	33.4	11.1	28.6

Table 2c

Employment (EM) and output (YD) by industry (in percentages)

	Primary industry		Manufacturing		Commerce	
Year	EM	YD	EM	YD	EM	YD
1952	56.1	32.2	12.4	12.9	10.6	17.9
1960	50.2	28.5	14.8	19.1	10.0	15.3
1970	36.7	15.5	20.9	29.2	13.6	14.5
1980	19.5	7.7	32.9	36.0	16.2	13.1
1989	12.9	4.9	33.9	34.6	19.4	14.6
1990	12.8	4.2	32.0	33.3	19.6	14.2
2000	7.8	2.1	28.0	26.4	22.8	19.3
2001	7.5	1.9	27.6	25.3	23.1	19.4

Table 3
Benchmark Parameter Values and Calibration

Benchmark Parameters and Observables		
per capita real economic growth rate	g	0.0648
aggregate consumption-aggregate output ratio	x/y	0.73
capital-output ratio	k/y	2.1
fraction of time devoted to employment	n	0.13
fraction of time devoted to education	e	0.12
capital's share	α	0.337082
coefficient of the cost of vacancy creation and management	ϕ	0.286414
cost elasticity of vacancy creation and management	ε	0.5
capital's depreciation rate	δ	0.063771
exogenous human capital accumulation rate	ζ	0.04
labor searcher's share in matching production	β	0.4
job separation rate	ψ	0.02
time preference rate	ρ	0.03
coefficient of goods technology	A	1
coefficient of matching technology	B	0.25
maximum rate of endogenous human capital accumulation	D	0.206667
Calibration		
capital rental rate	r	0.160540
job finding rate	μ	0.242795
search intensity	s	0.014281
vacancy creation	v	0.001020
vacancy creation cost	Φ	0.0028926
employee recruitment rate	η	0.254922
wage rate	w	0.375786
wage discount	Υ	0.611249
firms' residual consumption	z	1
marginal valuation of leisure	Λ_1	5.304929

Table 4
Simulation Results for Comparative Statics

	g	*n*	*e*	*s*	μ	η	*v*
Benchmark	**0.0648**	**0.130000**	**0.120000**	**0.014281**	**0.242795**	**0.254922**	**0.010200**
ζ up 1%	0.065299	0.130109	0.120479	0.014272	0.243300	0.254569	0.010222
D up 1%	0.103968	0.137174	0.306457	0.017442	0.282717	0.230320	0.011912
B up 1%	0.068763	0.131567	0.139174	0.014134	0.255283	0.250662	0.010498
ϕ down 1%	0.069425	0.131853	0.142381	0.014095	0.257791	0.244937	0.010766