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Barriers to Accumulation and Productivity Differences in a Two Sector Growth Model

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Abstract

Barriers to investment are often regarded as an important determinant of the variation in international income levels. Nevertheless, in the standard neoclassical growth model, these barriers have only have small effects on per capita incomes. We consider the effects of barriers to accumulation in a two-sector neoclassical model that also exhibits barriers to labor mobility. Numerical simulation show that barriers to accumulation have a magnified effect in this model. The results imply that if labor markets are not efficient, then barriers to accumulation may be an important determinant of a country's income level. Moreover, we show that the removal of these barriers can produce several decades of rapid growth, reminiscent of economic growth miracles.

J.E.L Classifications: O, O4, O41

Keywords: Economic Growth, Economic Development, Dual Economy, Barriers, Fragmented Labor Markets, Total Factor Productivity.

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1 Introduction

Can the presence of barriers to capital accumulation account for the enormous disparities in international per capita incomes across countries? A number of papers following Mankiw, Romer and Weil (1992) find that differences in capital-output ratios do account for the variance in international income levels. Nevertheless Prescott (1998) and Parente and Prescott (2000) use calibrated neoclassical growth models to show that only productivity based explanations for income differences are consistent with both observed international income differences and data on broad macroeconomic aggregates.

In this paper we consider whether the relatively modest effects of barriers to accumulation on income levels predicted by a standard neoclassical growth model, might be magnified in an economy where factor allocation is inefficient. This question is motivated by the observation that traditional and modern production techniques often co-exist within in developing economies, and that the use of traditional production methods can be encouraged by policy and institutional barriers to entry into the formal sector of the economy.

We find that the presence of this type of barrier substantially magnifies the impact of barriers to accumulation on income levels. This is because the removal of barriers to accumulation is associated with net productivity gains as labor is re-allocated to the capital intensive sector, where it has a higher marginal product. Moreover we show the removal of barriers to capital accumulation can result in a burst of growth that lasts over 20 years, and which can quantitatively account for the accelerated growth rates of growth miracle economies. We conclude that policies that liberalize capital markets and decrease the cost of investment, may be critical in generating productivity growth. This mechanism is likely to be important for developing economies, where institutional barriers in factor markets are prevalent and traditional production methods are widespread.

The paper is organized as follows. Section 2 briefly describes the relevant background

issues and reviews some of the existing literature on differences in income levels. In Section 3 we describe a simple two-sector neoclassical model, which features a traditional land intensive technology and a modern capital intensive technology. The model also allows for barriers to capital accumulation, and barriers to efficient resource allocation. We then conduct numerical simulations to determine the potential long run impact of the removal of these barriers through policy reforms, and these are described in Section 4. In Section 5 we then consider the implications of these experiments for short to medium term growth rates, by explicitly solving the transition paths for the economy. Section 6 then reviews the results and concludes.

2 Background and Related Literature

There exists a substantial body of recent literature on the effects of barriers and policy distortions on income levels and patterns of growth. One view expressed in this literature is that differences in capital per worker are an important source of the disparities in international income levels, Mankiw et al. (1992), Barro and Sala-i Martin (1995), Mankiw (1995), and Chari, Kehoe and McGrattan (1996). Likewise Jones (1994) and Restuccia and Urrutia (2001) have emphasized the importance of barriers to capital accumulation as a source of low income levels. This literature also shows that the effects of capital deepening tend to understate observed income disparities, unless a broad notion of capital is used, including intangible capital or human capital.

The alternative view is that differences in output per person across countries is mainly due to differences in total factor productivity (TFP). Thus Prescott (1998) finds that differences in investment rates across countries are not large enough to explain the variation in income levels.¹

¹See also Hall and Jones (1999) and Parente and Prescott (2000) As pointed out by Caselli (2003), however, it is difficult to evaluate the importance of each approach because both rely on the presence of

The approach adopted in this paper is to quantify the interaction between structural change and productivity growth in an economy where factors are not allocated efficiently. Following the approach of Parente and Prescott (2000), Restuccia and Urrutia (2001), and Gollin, Parente and Rogerson (2004), we consider the impact of barriers to capital accumulation. Within this setting, however, we also introduce barriers to labor mobility. Thus in the following model, the marginal product of labor in the modern sector exceeds the traditional sector, but institutional constraints on labor markets, prevent the economy specializing in the superior technology.

Our methods follow an extensive recent literature in which multi-sector neoclassical growth models are used to evaluate aspects of the development process.² Two papers which are closely related to the present study are Graham and Temple (2001), and Restuccia (2004). Restuccia poses the same question as our present study: does a two-sector model with productivity differences amplify the effect of barriers to accumulation on income levels? In Restuccia's model, however, the effects of barriers to capital accumulation on income levels are identical to a standard one-sector neoclassical model.³ Graham and Temple (2001) use simulation methods to bring some quantitative insight to the development-trap literature, which focuses on economies of scale and other types of

unobserved inputs, TFP or intangible capital. See also Bosworth and Collins (2003) for a useful survey of this empirical literature.

²The recent growth literature has tended to abstract from the issues of structural change emphasized in development economics. Recently however, a number of studies have used multi-sector neoclassical models to explore different aspects of growth, such as: the timing of industrialization, Hansen and Prescott (2002), Gollin (2002a), Ngai (2003); the behavior of savings rates, Laitner (2000), regional convergence, Caselli and Coleman (2001); Japan's growth performance; Hayashi and Prescott (2003), urban-rural migration Lucas (2004), and the pattern of growth rates over time, Echevarria (1997), Robertson (1999). This recent literature owes an intellectual debt to models of technological dualism, which were developed by Nelson (1954), Eckaus (1955), and Lewis (1954). The literature on dual economies more generally is vast, but seminal contributions include (Jorgenson (1961), Ranis and Fei (1961), Schultz (1964), Dixit (1968), Harris and Todaro (1970), Ohkawa and Rosovsky (1973) and Fields (1975). A recent related literature aims to quantify the effects structural change using cross regressions. These include Dowrick and Gemmell (1991), Landon-Lane and Robertson (2003), Chanda and Dalgaard (2003) and Temple and Woßmann (2004). The present study can be seen as exploring the quantitative implications of these econometric results through numerical simulations.

³See Landon-Lane and Robertson (2004) for a discussion of this point.

externalities, as a source of differences in income levels across countries.⁴ Our approach differs fundamentally from theirs in that we aim address the debate over the empirical applicability of the neo-classical model. Thus we aim to quantify the extent to which such models might account for differences in international income levels, without recourse to non-convex or linear technologies.⁵

This paper is also related to Parente, Rogerson and Wright (2000) and Gollin et al. (2004) who consider simulation results of policy distortions in multi-sector neoclassical models that feature home production. Parente et al. (2000) show that barriers to capital accumulation can cause high levels of home production, which is mis-measured. Thus, in their model, differences in international income levels partly reflect differences in measurement of output across countries. Gollin et al. (2004) use a similar model to investigate whether home production can explain differences in measured productivity levels between agriculture and industry, where home productivity is more prevalent in the former. Thus our present paper complements these two studies in that we abstract from home production in order to focus on the effects of incorporating barriers to factor mobility between sectors and the possibility that labor reallocation may generate aggregate productivity gains.

3 The Model

We consider a neo-classical growth model with one capital good. The economy consists of two types of agent, households and firms. A representative household owns three factors, capital, K_t , labor, N_t and a fixed factor, V_t . Firms are assumed to be com-

⁴Examples of this literature are Ciccone and Matsuyama (1996) and Rodrik (1996).

⁵Several other studies are complementary to the present paper. Restuccia, Yang and Zhu (2004) also look at the effect of barriers to accumulation in a two-sector model. Their focus however is quite different in that they explore policy distortions that raise the price of intermediate inputs in Agriculture. In addition they assume fairly special case where the production technology in non-agriculture is linear. Likewise Chanda and Dalgaard (2003) also discuss a model which has some similar features to ours, however they do attempt to quantify the structural equations of their model.

petitive price takers. They maximize profits in each period, taking the factor prices, $\{w_{a,t}, w_{m,t}, r_t, q_t\}$, as given.

Within this setting we assume two technologies exist, *modern* and *traditional*. Both technologies can be used to produce a single homogenous good. The output of either sector can be used for consumption, C_t , or spending on investment, X_t . There are no scale effects and the long run growth rates is exogenous. Likewise there are no externalities, so that markets are efficient. Nevertheless we allow for two policy distortions, so that in general, the equilibrium we describe in the model is not socially optimal. As discussed below, these policy distortions affect the steady state capital stock per effective worker and the allocation of labor between the two sectors.

3.1 Technology

We denote output of modern sector firms as Y_m and output of traditional sector firms as Y_a . Both techniques require capital and labor, but traditional production also requires inputs of the fixed factor, as in Hansen and Prescott (2002). The production functions for each sector are,

$$Y_{m,t} = K_{m,t}^\beta (\tilde{B}_t N_{m,t})^{1-\beta}, \quad (1)$$

$$Y_{a,t} = K_{a,t}^\alpha (\tilde{A}_t N_{a,t})^\lambda V^{(1-\alpha-\lambda)}. \quad (2)$$

Modern sector labor productivity is \tilde{B}_t , and grows exogenously at rate $\tilde{B}_{t+1}/\tilde{B}_t = \gamma$, where $\gamma > 1$. Traditional labor productivity is \tilde{A}_t and grows at a rate $\tilde{A}_{t+1}/\tilde{A}_t = \eta$.

3.2 Barriers

An important literature has recently emerged on the effects of distortions on growth rates, much of which is motivated by the descriptive accounts of De Soto (1989). In

particular Parente and Prescott (2000) show that these types of institutional constraints and discretionary policies can have a profound effects on per capita income levels, by reducing total factor productivity levels. They also argue that these distortions may affect steady state capital output ratios by distorting the relative price of investment. Nevertheless Parente and Prescott (2000) find that in the standard neoclassical growth model, the observed differences in international income levels cannot be explained by differences in per-capita output levels alone.

As discussed above, this conclusion stands in contrast to studies such as Mankiw et al. (1992), and Chari, Kehoe and McGratten (1997). Likewise the potential role of this type of distortion has been emphasized by Easterly (1993), Jones (1994) Restuccia and Urrutia (2001), who find that many developing countries have substantially higher relative prices for investment goods, compared to developed economies. In the present study, therefore, we consider whether these apparent barriers to capital might not be of greater importance in determining income levels, if they are combined with distortions in factor markets.

Specifically we consider the effect of barriers to accumulation on income levels in an economy where access to the formal or non-traditional sector of the economy is rationed. According to De Soto (1989) labor market barriers are an important contributing factor to the existence of large informal sectors. He finds that excessive regulation, employment restrictions and a high tax burden and corruption that raise the costs of establishing and running firms in the modern sector. Evidence for rationing of primary sector jobs in developing economies, is also provided by Basch and Paredes-Molina (1996), Teal (1996), Ruiz De Castilla, Woodruff and Marcouiller (1997).⁶ In particular Söderbom and Teal (2004) find that high modern sector labor costs, result in higher wages, reduced labor employment and more capital intensive methods.⁷ Labor market barriers may, therefore,

⁶There is also evidence of a relationship between technology capacity of firms and wage levels in developing economies. This includes Rebitzer and Robinson (1991), Lillard and Hong (1992) and Tan and Batra (1997). This is consistent with technical explanations such as efficiency wages.

⁷Models with this type of labor market barrier have also recently been explored by Loayza (1996),

take the form of rent extraction by bureaucrats or rent sharing by labor unions. They may be supported by high degree of corruption as well as union wage regulations, and regulatory restrictions on both hiring and job termination, such as severance payments, that also serve to restrict firms employment of labor in the modern sector.

The modeling of these barriers is standard. In incorporating barriers to capital accumulation we follow Parente and Prescott (1994), Gollin et al. (2004) and Parente et al. (2000), and assume that real investment is given by X_t/π , where X_t is nominal investment spending and π is a parameter that represents the efficiency of investment spending. Thus a higher value of π represents a higher levels of barriers so and investment spending is inefficient.

Likewise we characterize barriers to entry in the modern sector by assuming a wedge exists between the marginal product of labor in the modern sector and the traditional sector. Specifically we assume institutional barriers create a wage premium $\mu \geq 0$, which is paid by modern sector firms.

3.3 Household Behavior

An infinitely lived household chooses an optimal consumption path given its factor income receipts. Thus it chooses a sequence of consumption values, c_t to maximize utility. The household's utility function is,

$$U_t = \sum_{t=0}^{\infty} \theta^t N_t u(c_t), \quad (3)$$

and Satre (2000). These models stress the correspondence between the level of informal sector activity and the level of corruption. Also related is the literature on rent seeking and bureaucracy, Murphy, Shleifer and Vishny (1993), Shleifer and Vishny (1993), and Keefer and Knack (1995) who find evidence of a negative relationship between growth and corruption in cross-country data.

where $u(c) = c^{1-(1/\sigma)}/(1 - (1/\sigma))$, $\sigma \neq 1$, and $u(c) = \ln(c)$, $\sigma = 1$, N is the total number of workers.

The household's current consumption and investment decisions affects their their wealth.

Hence

$$K_{t+1} - K_t = X_t/\pi - \delta K_t, \quad (4)$$

where π is a measure of barriers to accumulation, as discussed above, and X_t/π is real investment. It can be shown that (4) gives rise to the following representative household budget constraint.

$$k_{t+1} - k_t = \frac{w_{a,t} n_{a,t} + w_{m,t} n_{m,t} + (r_t + \delta)k_t + q_t v_t - c_t}{(1 + \phi) \pi} - \frac{(\phi + \delta) k_t}{(1 + \phi) \pi}, \quad (5)$$

where: $n_{m,t}$ and $n_{a,t}$ are the relative stocks of labor employed in each sector; k_t is capital stock per worker; $v_t \equiv V/N_t$, is the per worker stock of the fixed factor; $w_{m,t}$ and $w_{a,t}$ are wages earned in each sector; r_t is the rate of return in the bond market; δ is the rate of depreciation on physical capital; $r + \delta$ is the rental rate earned on physical capital; q_t is the rental rate of the fixed factor, and; ϕ is the exogenous growth rate of labor, $\phi = N_{t+1}/N_t$.

3.4 Equilibrium

Given initial conditions K_0 , N_0 , barriers, π and μ , a competitive equilibrium consists of sequences for $t \geq 0$ of factor allocations $\{K_{m,t}, K_{a,t}, N_{m,t}, N_{a,t}\}$, factor prices $\{r_t, w_{a,t}, w_{m,t}\}$, rents to fixed traditional assets, q_t , and consumption decisions c_t , such that: (i) household's maximize utility subject to (12) taking factor allocations and factor rentals as given; (ii) firms maximize profits given factor rentals; (iii) firms earn zero profits, and; (iv) markets clear such that income is equal to expenditure, $Y_t = N_t c_t + X_t$, capital and labor are fully employed, $K_t = K_{m,t} + K_{a,t}$, and $N = N_{m,t} + N_{a,t}$.

Profit maximization by firms then implies the following factor market clearing conditions:

$$\beta Y_{m,t}/K_{m,t} = \alpha Y_{a,t}/K_{a,t} = r_t + \delta; \quad (6)$$

$$(1 - \alpha - \lambda) Y_{a,t}/N_{a,t} = w_{a,t}; \quad (7)$$

$$(1 - \beta) Y_{m,t}/N_{m,t} = w_{m,t}; \quad (8)$$

$$w_{a,t}(1 + \mu) = w_{m,t}. \quad (9)$$

As shown in the appendix, the Household's optimal consumption path is described by the following Euler equation,

$$c_{t+1}/c_t = \theta^\sigma [(r_{t+1}/\pi + 1 - \delta((1 - \pi)/\pi)]^\sigma. \quad (10)$$

3.5 Balanced Growth Path

The existence of a balanced path is not guaranteed without specifying the productivity growth rates in each sector. A standard result in this class of model is that productivity in the traditional sector must exceed the growth rate in the modern sector, Caselli and Coleman (2001), Hansen and Prescott (2002).⁸ We therefore assume that traditional productivity grows at rate $\eta = \gamma^{1-\alpha}/\lambda \phi^{1-\lambda}/\lambda$. Under this assumption the economy has a balanced growth path equilibrium, as defined in Definition 1.

Definition 1: A balanced path equilibrium is defined as competitive equilibrium such that K_t , $K_{m,t}$, $K_{a,t}$, $Y_{a,t}$, $Y_{m,t}$, Y_t and C_t are all growing at the rate $\phi \gamma$, and $n_a = N_{a,t}/N_t$ and $n_m = N_{m,t}/N_t$ are constant.

⁸These studies cite evidence that agricultural productivity has risen faster than other sectors. This assumption is less appealing if we are considering a traditional sector, rather agriculture per se. However we may think of productivity growth, in this context, as land clearing.

It follows that on the balanced growth path we have $c_{t+1}/c_t = \gamma$, and the marginal product of capital is constant and equal to $r^* + \delta$. Hence on a balanced path, (10) can be written as,

$$(r^* + \delta)/\pi = \gamma/\theta^\sigma - (1 - \delta). \quad (11)$$

This equation shows that on a balanced path there is a directly proportional relationship between the level of barriers to capital accumulation and the marginal product of capital. As discussed below, this balanced path constraint can be used to place an upper bound on the value of π .

4 Steady State Results

In this section we use the preceding two-sector model, with barriers to capital accumulation and employment, to investigate the extent to which these barriers can help explain the large differences in income levels across countries. To do this we present numerical results from a calibrated version of the preceding model.⁹

4.1 Calibration

First we calibrate the model to fit some stylized facts corresponding to a developing economy. Thus in the benchmark equilibrium we have a large employment share in the traditional sector, high level of barriers to capital accumulation $\pi > 1$ and barriers to employment in the modern sector, $\mu > 0$.

Using Penn World Tables data on the relative price of investment, Restuccia and Urrutia (2001) estimate cross country differences in barriers to capital accumulation. They find that investment prices differ across countries by a factor of up to ten-fold. It should be

⁹This method follows the approach of Parente et al. (2000) and Restuccia (2004).

noted, however, that from (11) in an economy with $\pi = 10$, the steady state rental rate on capital, $\bar{r} + \delta$ would be ten times the level of an economy with $\pi = 1$. Thus higher level of barriers may imply unrealistic differences in the return to capital. In view of this we assume an initial value of $\pi = 4$.¹⁰ As suggested, a barrier of $\pi = 4$ implies a four-fold change in the return to capital between the two steady states.

Next consider the employment share of the traditional sector. As a first approximation this can be inferred from data on agricultural employment shares. According to the United Nations Food and Agricultural Organization (FAO), in the year 2000 there were 33 countries with agricultural shares of employment exceeding 70%, and is as high as 93% in Bhutan and Rwanda. However our notion of traditional sector is broader than just agriculture. For instance measures of employment in the urban informal sector are often greater than 50% of the urban labor force in developing economies, and may be as high as 70%, International Labour Office (2003). We assume, therefore, that initially the traditional sector consists of all agricultural employment plus 2/3 of the employment of non-agriculture. Hence an agricultural employment share of 70% implies an traditional sector share of 90% of the labor force, $n_a = 0.9$.

To quantify the degree of labor market distortion in developing economies, as represented by the size of μ , we consider evidence from sectoral wage gaps and urban-rural wage differentials. Though there is clear evidence of large nominal wage gaps between informal and formal sectors, and urban and rural sectors, the evidence on real wage gaps is less clear. Nevertheless, surveys by Fields (1980), Squire (1981), Hatton and Williamson (1991), and World Bank (1995), suggest that real wage differences of 30-50 percent, or higher, are not unrealistic for less developed economies. Likewise individual country studies of wages in formal and informal sectors often find similar real wage differentials.¹¹ Further

¹⁰This value is also chosen as a reference point by Parente et al. (2000) and Restuccia (2004).

¹¹Ruiz De Castilla et al. (1997) find residual real wage gaps of between 12% and 56% in Peru and El Salvador, and Basch and Paredes-Molina (1996) find gaps of around 50% Chile, and Söderbom and Teal (2004) report similar numbers for Ghana.

evidence is given by Temple and Woßmann (2004) who estimate real labor productivity differences in excess of 100% in cross country data, though find that these have declined over time.¹² In the experiments below therefore we consider the range of values from $\mu = 1$ to $\mu = 0$. The latter case corresponds to a standard neoclassical model where, despite the presence of two sectors, the aggregate implication of barriers is identical to the standard one sector model.

Finally we normalize real GDP per worker in the base case to equal unity. Likewise the total labor supply is normalized to unity. Thus in the initial benchmark, which corresponds to the income level of a less developed economy, we have $y = c + (x/\pi) = 1$, where $\pi = 4.0$.

The remaining parameters are standard, and all parameter values are reported in Table 1. Specifically we assume that the capital income share in the modern sector is $\beta = 0.35$, and labor's share is the same in both sectors $1 - \beta = \lambda = 0.65$. The assumption of equal shares across sectors is consistent with evidence on labor shares in agricultural and non-agriculture presented by Gollin (2002a), and is a standard assumption in models with agricultural and non-agricultural sectors, Gollin et al. (2004), Restuccia (2004). Finally we choose $\delta = 0.06$ and choose θ such that the market steady state interest rate, when $\pi = 1$, is $r^* = 0.08$.

4.2 Quantifying the Long Run Effects of Barriers to Capital Accumulation.

To quantify the effects of barriers in this economy we resolve the model for counterfactual values of μ and π , holding the all technical parameters constant, and allowing the endogenous variables, c_t , $n_{a,t}$, $k_{a,t}$ and $k_{m,t}$ and y_t to adjust to their balanced path

¹²Similar evidence from cross sectional data is presented by Landon-Lane and Robertson (2003), though Dowrick and Gemmell (1991) present more modest results.

Table 1: Calibrated Parameters

Parameter	Value	Target
γ	1.020	growth of aggregate productivity of 1.02
ϕ	1.019	growth rate of labor of 1.019
β	0.350	labor income share in modern sector of 0.65
α	0.250	income elasticity of land of 0.1
λ	0.350	labor income share in traditional sector of 0.65
θ	0.944	long run rate of return to capital of 8 percent
δ	0.060	rental price of capital of 14%
B	1.922	normalization of aggregate output to 1
A	1.265	traditional sector employment share, $n_a=0.9$

values. For clarity we denote the benchmark values of μ and π as $\bar{\mu}$ and $\bar{\pi}$, and the counterfactual values as $\hat{\mu}$ and $\hat{\pi}$. Thus in the benchmark equilibrium we have $\bar{\mu} \geq 0$, $\bar{\pi} = 4$. As discussed above, in the benchmark the technology parameters are calibrated so that $n_a = 0.9$ and $y = 1$.

The main experiment we consider is to simulate the effect of a decline in π from $\bar{\pi} = 4$ to $\hat{\pi} = 1$ and a decline in μ from $\bar{\mu} = 1$ to $\hat{\mu} = 0$. This simulates the effect of removing all barriers. Table 2 reports the results of this experiment, and the first column of Table 2 shows the counterfactual equilibrium level of per capita income when all barriers are removed, $\hat{\mu} = 0$ and $\hat{\pi} = 1$.

Table 2: Gains in real GDP from removing all barriers: $\hat{\pi} = 1$, $\hat{\mu} = 0$

$\bar{\mu}$	y	n_a
0.00	2.45	0.107
0.25	2.99	0.020
0.50	3.51	0.005
0.75	4.00	0.002
1.00	4.47	0.000

First consider the case where there is no barrier to employment in the initial equilibrium, $\bar{\mu} = 0$. In this case our two-sector model behaves exactly like the one-sector neoclassical growth model. Thus the removal of barriers from a level of 4 to 1, raises real GDP per

worker by factor of 2.45. While significant, Prescott (1998) argues that values of this magnitude are quite modest relative to the differences in international income levels. For example, economic miracle economies have experienced approximately seven-fold increases in per capita over several decades. Likewise per capita incomes between the richest and poorest countries, differ by a factor of approximately 30, Parente and Prescott (2000).

Next we consider the results when $\bar{\mu} > 0$. It can be seen that the combined effect of removing barriers increase to 3.5 when $\bar{\mu} = 0.5$, and increases to 4.5 when $\bar{\mu} = 1$. Thus the removal of these barriers can potentially explain a large fraction of the differences in observed income levels. Specifically the contribution increases from a 2.5-fold difference in income levels, to a 4.5-fold difference. These values imply that policies aimed at removing barriers to capital accumulation may be substantially more important than is suggested by the standard growth model with efficient factor markets.¹³

To understand the source of this amplified contribution of barriers to capital, it is informative to decompose this difference in per capita incomes into the resource mis-allocation effect from barriers in the labor market, and a dynamic effect from barriers to capital accumulation. Hence we report two additional experiments in Tables 3 and 4. Table 3 reports reports the results of removing labor market barriers only - reducing μ , but holding π constant at the initial level. Thus the results record the comparative steady state output change in per capita income and employment. It can be seen that the per capita income gains range from 1.17 ($\bar{\mu} = 0.25$) to 1.73 ($\bar{\mu} = 1.0$).

Table 4 reports the effects of reducing barriers to capital, holding the labor market

¹³These results are sensitive to the value of the capital share, β in the modern sector. If we include intangible capital and human capital a more reasonable capital share might be a number close to 2/3. With these capital shares, a change in π induces much larger increases in GDP per worker. However Parente and Prescott (2000) argue that these models imply implausibly large changes in intangible capital and education investment rates. For this reason we focus on the more conventional neoclassical model with a capital share equal to 0.35. Nevertheless our analysis carries over to the alternative specification. For example, with a modern sector capital share of $\beta = 2/3$, a reduction in π from 2 to 1 results in an eight-fold increase in GDP per capita in when there is no barrier to a 13 fold increase when $\bar{\mu} = 1$.

Table 3: Removing Barriers to Labor Only, ($\hat{\mu} = 0$, $\hat{\pi} = \bar{\pi} = 4$)

$\bar{\mu}$	y	n_a
0.00	1.00	0.900
0.25	1.17	0.169
0.50	1.36	0.043
0.75	1.54	0.014
1.00	1.73	0.005

barriers constant, $\hat{\mu} = \bar{\mu}$. It is immediately apparent that these output gains are almost as large as the results in Table 1, so that the removal of the capital barriers alone is sufficient to realize the amplified output gains. This is because removing barriers to capital accumulation induces sufficient demand for labor in the modern sector relative to the traditional sector, to overcome the additional costs of modern sector labor. Hence once most of the labor is reallocated to the modern sector, the labor market barriers are largely redundant.

Table 4: Removing Barriers to Accumulation Only, ($\hat{\mu} = \bar{\mu}$, $\hat{\pi} = 1$)

$\bar{\mu}$	y	n_a
0.00	2.45	0.107
0.25	2.92	0.107
0.50	3.38	0.107
0.75	3.81	0.107
1.00	4.23	0.107

Thus the presence of a labor market barrier multiples the effect of barriers to accumulation, with or without labor market reforms. It can be seen further that this multiplier is approximately given by the costs of the labor market distortion. That is, the output gains in from removing labor barriers, in Table 3, are approximately equal to the ratio of the gains from removing barriers to accumulation in Table 4, relative to the gains when there are no labor market distortions, of 2.45.¹⁴

¹⁴For example when $\bar{\mu} = 1$, the gain in output from removing barriers to accumulation is 4.23. This

This then is the key insight from the experiments. Barriers to capital accumulation can have a large effect on labor demand in capital intensive sectors, and the removal of these barriers can, therefore, induce large labor re-allocation effects. In the presence of a difference in the marginal product of labor between sectors, however, these changes in sectoral labor demand also induce aggregate productivity growth. Thus the gains from removing barriers to accumulation are amplified by the presence of labor market distortions.

A second aspect of the results is the change in the sectoral distribution of labor. We note that the decline in barriers to capital accumulation are capable of accounting for the large changes in the sectoral composition of employment that is observed historically over the course of development. This structural shift is due to a Rybczynski effect - the increase in the aggregate capital labor ratio increases employment of both labor and capital in the relative capital intensive modern sector, Rybczynski (1955).¹⁵ In particular the magnitude of the shift does not depend on the presence of labor market barriers. Hence the results in Table 4 show that a reduction in barriers to accumulation generates enough growth in modern sector labor demand, to reduce traditional sector employment, n_a , from 90% to just 10% of the labor force, irrespective of $\bar{\mu}$. Thus the simulations also reproduce the stylized fact that employment in traditional land and labor intensive methods, decline rapidly as income levels rise.¹⁶

however is approximately equal to the gain in output from removing barriers to accumulation when there are no labor market distortions, 2.45, multiplied by the cost of the labor market distortion, 1.76.

¹⁵There remains an issue of robustness. We also consider values of $\lambda > 1 - \beta$, such that the traditional sector has a higher labor income share than the modern sector. In the appendix we report the results for a range alternative values of labor's income share, $1 - \lambda$. The land share of income is held constant at 10% in these experiments. This shows that higher labor shares in the traditional sector will lead to larger shifts in employment and larger effects on income levels. These effects however can be seen to differ only marginally from the values presented in Table (2). Hence the value of labor's income share in the traditional sector, is not a critical factor in the results. A second issue is that we have only presented results for the case where $\pi = 4$. Detailed tabulations of the results for a large range of values of π are available from the authors upon request. We do not report these however as they change the results in a predictable fashion. Likewise we have also compiled results for alternative factor shares. In particular, as is well known, when the capital share of income becomes large, barriers to capital accumulation have correspondingly larger effects on income levels.

¹⁶Traditional methods may include traditional agriculture, manufacturing and services such as house-

4.3 Discussion

We have shown that the gains from removing barriers to accumulation may be substantial in countries where substantial resource allocation problems exist. This, then, is a potentially important extension to the results of Prescott (1998) and Parente and Prescott (2000) who consider these effects in models with perfect factor markets. Likewise our results complement Parente et al. (2000) and Gollin et al. (2004) who show that barriers to capital may have relatively large consequences for measured income levels and the number of hours worked.

It is useful to consider briefly how our results compare to more standard models of development that emphasize agriculture and industry sectoral differences. In particular Schultz (1964) argued that the transformation of agriculture is a precondition to successful development. Our model has two technologies but only one commodity. Hence our model is consistent with Shultz's theory. That is, the reduction in barriers to accumulation generates higher demand for labor in the modern sector which, by definition, includes modern agricultural production methods. Likewise our results are consistent with Caselli (2003), who finds that differences in the commodity-sectoral allocation of labor across countries cannot account for the international variation in income levels, and that within-commodity-sector productivity differences are large. Nevertheless, whereas Caselli (2003) concludes that factor accumulation effects are unimportant, our model and results stress the possibility that barriers to accumulation can affect aggregate productivity by altering the mix of traditional and modern technologies being used within each sector.

It may be noted, further, that the differences in output we obtain from these simulations are much larger than the static welfare costs of resource allocation. For example, Temple (2003) has recently looked at this issue in the context of the current growth debate,

hold services, street hawking and handicraft production.

and concluded that wage gaps only have small effects on aggregate productivity. The difference between his results and the results herein are that: (i) we focus on differences in total output levels, not productivity levels or welfare gains, and (ii) our results are obtained in a dynamic model where capital accumulation is endogenous. Hence our results come from the interaction between the static and dynamic costs of each type of barrier. Thus the apparently differing results largely reflect the different questions being posed.

Lastly, an appealing aspect of the results is that they are consistent with the recent growth accounting literature, such as Young (1995) and Collins and Bosworth (1996). Young in particular, finds that measured productivity growth rates in the non-agricultural sector were not particularly high in East Asian Miracle economies. On the other hand capital accumulation did account for a large share of growth in these countries. In our model, high levels of productivity growth at the aggregate level can occur, even though productivity growth within a particular sector may be modest.

5 Transitions and Growth Miracles

In the introduction we claimed that barriers to accumulation may also be important in understanding growth miracles. In particular, whereas numerous studies have emphasized the importance of technology transfer, growth accounting studies of the East Asian Miracle, such as Young (1995), do not find extraordinarily high rates of productivity growth in the non-agricultural sector.

The preceding results show that potentially, the removal of barriers to capital accumulation can generate large changes in income, in an economy which exhibits large productivity disparities between traditional and modern sectors. It is also informative however to briefly consider the transition paths generated by these changes.

To generate the time path for the economy after the reforms, we solve the transition paths from the initial date where the reform is announced, until the new steady state. Solving the model presents us with a two point boundary value problem, which can be solved using shooting methods.¹⁷ This method finds the initial value of the control variable, c_t , that generates the unique path to the steady state, conditional on the state variable, K_t .

We consider a policy reform that results in the reductions in barriers, which follows the following policy rule.

$$\hat{\pi}_{t+1} - 1 = \rho_\pi (\hat{\pi}_t - 1), \rho_\pi < 1$$

where ρ_π is chosen such that $\ln \rho_\pi = (\ln(0.5)/h_\pi)$, where h_π is the half-life for the reform process. We then consider various transitional growth paths, for different half-lives.¹⁸

The first experiment we consider is the reduction in barriers to accumulation in the case where $\bar{\mu} = 0$. Recall that in this case, there is no sectoral marginal productivity differential, and the model behaves exactly as the one sector neoclassical model. Figure (1) illustrates the growth rate of real GDP for $h_\pi \in \{2, 3, 5, 10\}$. It can be seen that a short half-life can generate very high growth rates though only for a short period of time. When the reform process is slower, however, the transitional growth rates are much less pronounced.

The effect of the labor market distortion can be seen in Figure (2) which compares the model with and without the distortion with a case where μ is constant and equal to 1. It can be seen that this generates higher growth rates for a similar period of time. To see how this compares with the evidence on growth miracles, Figure (3) provides a simple visual comparison of the predicted growth rates of the model in this case, $\mu = 1$, $h_\pi = 5$, with the actual growth rates for Japan, from The Penn World Tables.¹⁹ This shows that the

¹⁷This was solved using FORTRAN. The code is available from the authors upon request.

¹⁸The model was solved for 150 years. In each case the reform process was truncated so that π reaches its long run target value, $\hat{\pi}$, after 120 years.

¹⁹The dual nature of labor markets has featured heavily in many descriptive accounts of the development in Japan, for example see Fei, Ohkawa and Ranis (1985) and Hayashi and Prescott (2003).

model is capable of reproducing generating similar annual growth rates to those of Japan, of around 7-10%. Moreover, as in the Japanese experience, relatively high growth rates can sustained several decades. Thus incorporating the labor market distortion provides some potential for reconciling standard growth models with the observed transitional growth experiences in rapidly growing economies.

6 Conclusion

Our aim has been to show that if relatively large barriers in factor markets exist, then the removal of barriers to capital accumulation may have an amplified effect on income levels. In particular we found that barriers to capital accumulation amplify the economic costs of labor market distortions. Based on our experiments, the presence of large wage gaps in developing countries nearly doubles the effect of barriers to capital accumulation on income levels. In this sense, these types of barriers may well be an important cause of low income levels in developing economies that have large traditional sectors and large institutional barriers to labor mobility. Likewise this type of barrier may also account for a substantial fraction of the differences in international income levels.

Figure 1: Growth Rates of Real Output due to Policy Reform ($\mu = 0$)

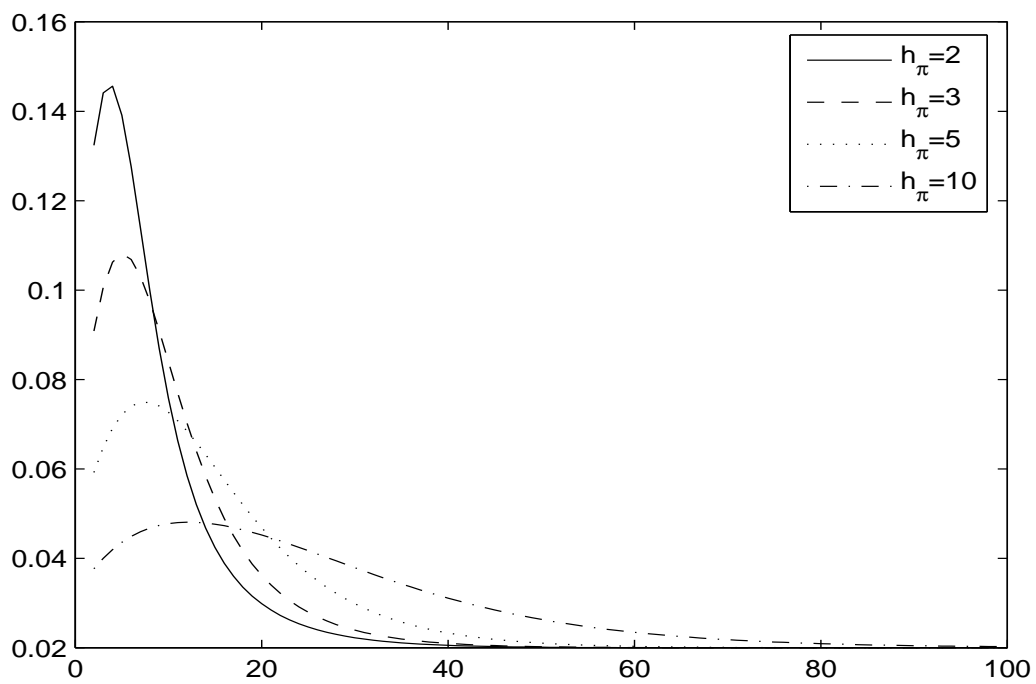


Figure 2: Effect of $\mu > 0$ on Growth Rates During Policy Reform ($h_\pi = 5$)

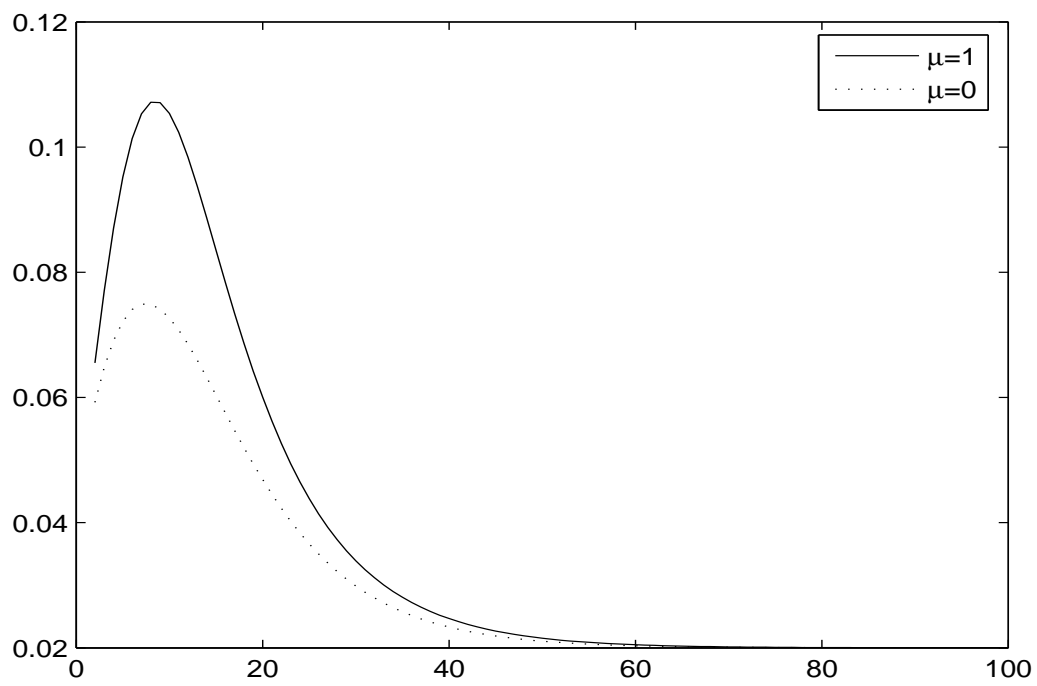
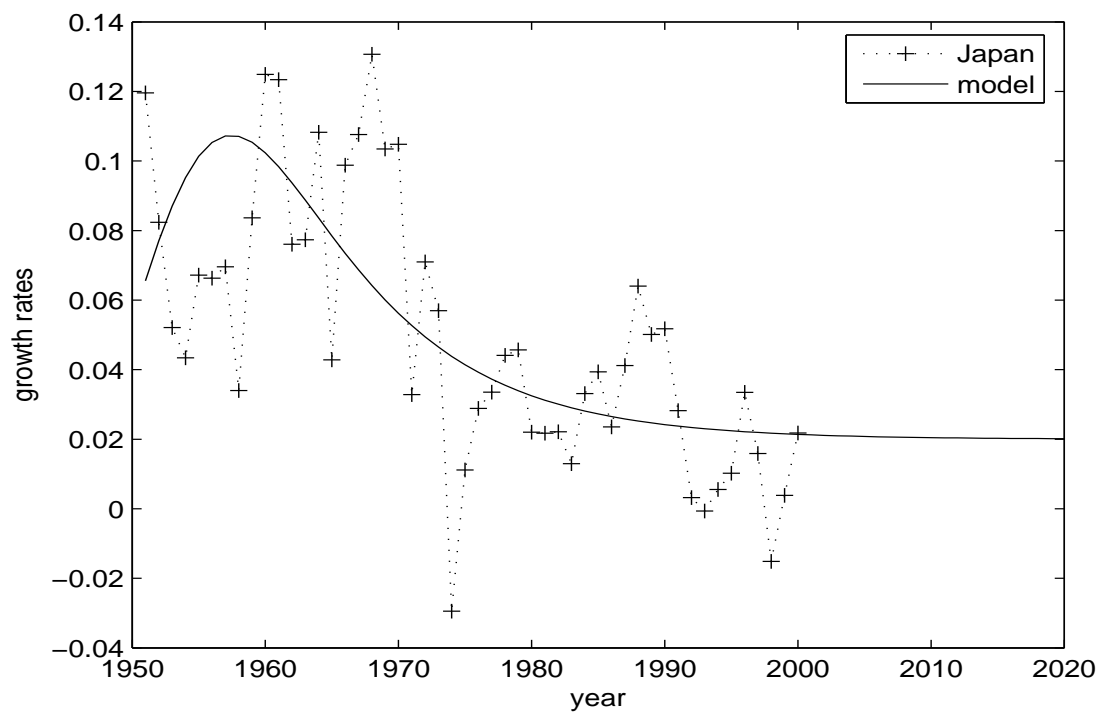


Figure 3: Growth Rates in Model Compared to Japanese Post War Growth($h_\pi = 5$)



7 Appendix

7.1 Sensitivity Tests: Results

Table 5: The Effects of Barriers on Income Levels, y : Alternative Values of Labor's Income Share, λ .

$\bar{\mu}$	$\lambda = 0.30$	$\lambda = 0.25$	$\lambda = 0.20$
0.00	2.54	2.64	2.72
0.25	3.11	3.22	3.32
0.50	3.64	3.77	3.89
0.75	4.15	4.29	4.42
1.00	4.64	4.79	4.93

Table 6: The Effects of Barriers on Traditional labor, n_a : Alternative Values of Labor's Income Share, λ .

$\bar{\mu}$	$n_a (\lambda = 0.30)$	$n_a (\lambda = 0.25)$	$n_a (\lambda = 0.20)$
0.00	0.037	0.013	0.004
0.25	0.006	0.002	0.001
0.50	0.001	0.000	0.000
0.75	0.000	0.000	0.000
1.00	0.000	0.000	0.000

7.2 Derivation of Equation (10)

The budget constraint for the representative household is,

$$K_{t+1} - K_t = [w_{a,t} N_{a,t} + w_{m,t} N_{m,t} + (r_t + \delta)K_t + q_t V - N c_t]/\pi - \delta K_t. \quad (12)$$

To derive the budget constraint for the representative household, we divide the aggregate budget constraint (12) by the population.

$$k_{t+1} - k_t = (w_{a,t} n_{a,t} + w_{m,t} n_{m,t} + r_t k_t + q_t v - c_t) / ((1 + \phi) \pi) - (\phi + \delta) k_t / ((1 + \phi) \pi) \quad (13)$$

The household utility maximization problem can be characterized by the following Lagrangian.

$$\begin{aligned} \max_{c_t, k_{t+1}} \mathbf{L} = & N_0 \sum_{t=0}^{\infty} \beta^{-t} (1 + \phi)^t u(c_t) \\ & + \lambda_t [k_{t+1} - k_t - (w_{a,t} n_{a,t} + w_{m,t} n_{m,t} + (r_t + \delta) k_t + q_t v) / (\pi (1 + \phi)) \\ & + c_t / (\pi (1 + \phi)) + k_t (\phi + \delta) / (1 + \phi)] \end{aligned} \quad (14)$$

The first order conditions for c_t and k_{t+1} , are:

$$N_0 \beta^t (1 + \phi)^t u'(c_{t+1}) + \lambda_{t+1} / (\pi (1 + \phi)) = 0, \quad (15)$$

and;

$$\lambda_t - \lambda_{t+1} [1 + r_{t+1} / (\pi (1 + \phi)) - (\phi + \delta) / (1 + \phi)] = 0. \quad (16)$$

Combining these gives the Euler equation,

$$u'(c_t) / u'(c_{t+1}) = \beta [(r_{t+1} + \delta) / \pi + 1 - \delta]. \quad (17)$$

With CES preferences, $u(c) = c^{1-(1/\sigma)} / (1 - (1/\sigma))$, $\sigma \neq 1$, (17) becomes,

$$c_{t+1} / c_t = \beta^\sigma [(r_{t+1} + \delta) / \pi + 1 - \delta]^\sigma.$$

which is equation (10).

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