Measuring the Miracle: Market Imperfections and Asia's Growth Experience*

John Fernald
Federal Reserve Bank
of San Francisco

Brent Neiman
University of Chicago
Booth School of Business

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Abstract

We discuss how market distortions, in theory and in practice, influence measures of total factor productivity in terms of quantities (the primal approach) and real factor prices (the dual). Many of these distortions reflect intentional government policies, such as capital subsidies or preferential tax treatment for some firms, which can make observed costs of capital unrepresentative. Pure economic profits can also be important, and drive wedges between factor shares in income and factor elasticities in production. These imperfections can cause primal and dual TFP growth measures to diverge from each other and from true technology growth. We apply our framework to reconcile divergent TFP estimates in Singapore and to resolve other important empirical puzzles regarding Asian development.

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1 Introduction

Many countries–rich and poor, fast growing and slow–have market distortions that affect the interpretation of productivity statistics.[1] Many of these distortions reflect intentional government policies, such as capital subsidies or preferential tax treatment for some firms. Other distortions reflect monopoly power which, in some cases, leads to large (and possibly varying) rates of pure economic profit. We discuss how these distortions, in theory and in practice, influence measures of total factor productivity in terms of quantities (the primal approach) and real factor prices (the dual). In particular, market imperfections can cause primal and dual TFP growth measures to diverge from each other and from true technology growth. We apply our framework to measure TFP and technology in Singapore. Our framework and results quantitatively reconcile the divergent findings of Young (1992, 1994, 1995) and Hsieh (2002)–thereby resolving a controversy that has generated heat but also considerable smoke. Our estimates also uncover increases in capital's share of production–consistent with trade-based explanations of Asia's growth–that were otherwise obscured by declining profit shares.

Policy interventions often favor some firms over others. For example, favored producers might receive subsidized financing or preferential tax treatment. Foreign firms might be offered such benefits as a means to encourage direct investment. We discuss how the resulting heterogeneity affects productivity measurement. The issues are particularly pronounced when, as is often the case, the subsidies and benefits are difficult to quantify. The effective user cost of capital for firms can then diverge from market-based measures as observed by a statistician. Dual TFP change which is based on changes in real factor payments, will then not, in general, equal true technology growth. The primal TFP calculation, by contrast, is less sensitive to this favoratism, since it does not directly use measurements of the cost of capital.

Further, consider countries where the economic profit share in certain sectors is large. This might reflect entry barriers erected to protect powerful incumbents, direct ownership of firms by the government, or other output market interventions. Large economic profits are particularly likely in economies characterized by heterogeneity in government's treatment of firms. Economic profits, however, are generally not observed by the statistician. Both primal and dual TFP calculations use

[1] The burgeoning literature on resource reallocation and misallocation highlights these distortions; see, for example, Restuccia and Rogerson (2009), Hsieh and Klenow (2009), and Banerjee and Moll (2010). Much of this literature focuses on developing countries, but many of the same issues apply to rich countries. For example, Basu and Fernald (2001) emphasized reallocations over the business cycle. Blanchard and Giavazzi (2003) emphasize labor and product market distortions in European economies.

the share of payments to capital as an input, but impute this share as the residual after subtracting wage payments from output. Hence, economic profits can cause dual and primal TFP growth to differ from each other and from technology growth.

We derive aggregate growth-accounting implications in a two-sector economy with these two types of distortions and demonstrate their joint impact on the ability of primal and dual TFP calculations to measure true changes in technology. We then apply our framework to the most prominent puzzle in growth accounting: the case of Singapore. Young's (1992, 1994, 1995) careful primal growth accounting established the new conventional wisdom that Singapore's rapid development did not involve technology growth. Two decades of growth of nearly 8 percent per year reflected the massive accumulation of capital and labor along with negative TFP growth. Hsieh (2002) challenges this view and finds that dual TFP in Singapore grew at a moderate pace. Table 1 compares these primal and dual estimates for Singapore as well as Hong Kong, Korea, and Taiwan – a group referred to as the newly industrialized economies (NIEs). These apparently contradictory results reflect the following puzzle. Labor's share in income was generally stable or rising. Hence, the rising capital-output ratio behind the weak primal TFP growth in Singapore implies a sharp decline in returns to capital; but, reasonable user-cost measures are flat.

We provide qualitative evidence that pure profits, capital subsidies, and differential tax treatment played an important role in Singapore's economy. In the context of our framework, we then quantify these imperfections and combine primal and dual results to shed light on sectoral and aggregate dynamics. For firms receiving preferential treatment, even Young's primal results were insufficiently pessimistic: Output grew nearly 10 percent per year for two decades, with sharply negative technology growth. Since this sector received large quantities of foreign direct investment, our results suggest that policies designed to lure FDI did not, in fact, raise overall TFP through technology transfer. The unfavored sector had annual output growth of about 6 percent with positive technology growth. Overall, technology growth was slightly negative. Further, we show how the imperfections we identify can quantitatively resolve most of the puzzling mismatch between Hsieh's dual and Young's primal TFP calculations for Singapore. We replicate the exercise in the other NIEs to demonstrate that, consistent with the data, our exercise does not imply large dual-primal TFP gaps for Hong Kong, Korea, and Taiwan.

Finally, we note the implication of our framework that labor's share of production costs was decreasing in most of the NIEs, despite labor's flat or rising share in revenue. Economic profit shares drove wedges between factor shares in revenues and in costs. Several international trade-based descriptions of Asia's growth, such as Ventura (1997) and Romalis (2004), involve structural transformations toward capital-intensive sectors and imply a decline in labor's share. Hence, in contrast to a face-value interpretation of the original growth-accounting results, our explanation also allows an important role for trade in the NIEs' sustained rapid growth.

In sum, we reconsider dual and primal growth accounting exercises under highly plausible and empirically prevalent conditions that drive a wedge between measured TFP and actual technology growth. We pay special attention to the differences between economic objects that influence activity and the data available to measure those objects. We apply our framework to TFP measurement in Singapore and demonstrate that our approach is able to reconcile a highly controversial gap between dual and primal estimates in the literature. Our explanation allows for important roles of the primal and dual growth accounting studies and the trade-based analyses in our understanding of the Asian growth experience. Previously, all of these results were pairwise mutually exclusive.

2 Growth Accounting in a Two-Sector Model with User-Cost Differences and Pure Profits

We model a simple, two-sector, partial equilibrium economic environment in which one sector earns pure profits, receives a capital subsidy, and faces a preferential tax rate. These features appear empirically important in resolving apparently contradictory estimates for Asian growth, but they are also likely to have much broader applicability. We begin by introducing notation and describing the firm problem. Next, we relate primal and dual TFP growth to true sectoral technology growth and to each other. Finally, we consider how a statistician might go about measuring TFP growth for the aggregate two-sector economy, and compare that measurement to actual aggregate technology. We show that profits and capital cost heterogeneity can drive a wedge between the dual and primal exercises and render both of them imperfect estimates of technology.

2.1 A Two-Sector Environment

Consider firms indexed by $i = F$ or U (ultimately, "favored" and "unfavored") that use homogeneous capital K and labor L, with $K_t = K_{F,t} + K_{U,t}$ and $L_t = L_{F,t} + L_{U,t}$. Each firm i has a Cobb-Douglas production function, $Y_{i,t} = A_{i,t} K_{i,t}^{\alpha_i} L_{i,t}^{1-\alpha_i}$, where $A_{i,t}$ is the firm's technology. The firms are equity-financed and seek, with perfect foresight, to maximize the present discounted value of cash flow.

Cash flow each period equals revenues net of wages, capital expenditures, and net taxes paid (we abstract from factor adjustment costs): $P_{i,t}Y_{i,t} - W_t L_{i,t} - (1 - \kappa_{i,t} - \tau_{i,t} D_{i,t}) I_{i,t} - \tau_{i,t} (P_{i,t}Y_{i,t} - W_t L_{i,t})$. The capital goods price, q, is the numeraire. The firms take the wage, W_t, as given and deduct wage payments before paying taxes at rate $\tau_{i,t}$. $D_{i,t}$ is the present value of allowances for depreciation in the tax code per dollar of investment; the tax authorities issue a credit of $\tau_{i,t}D_{i,t}$ when the firm undertakes the investment.[2] $\kappa_{i,t}$ is an investment subsidy, so that $(1 - \kappa_{i,t} - \tau_{i,t}D_{i,t}) I_{i,t}$ is the firm's effective net expenditure on capital. If the firm has market power, then price $P_{i,t}$ (relative to the capital goods price) depends on its choice of output: $P_{i,t}(Y_{i,t})$. Capital accumulation is a function of investment $I_{i,t}$ and depreciation δ: $K_{i,t+1} = (1-\delta) K_{i,t} + I_{i,t}$. i_t is the real interest rate between $t-1$ and t (with $i_0 \equiv 0$), again defined in terms of the numeraire q, so that $\prod_{j=0}^{t} (1+i_t)^{-1}$ is the firm's discount rate from period 0 to period t.

We assume perfect foresight and write the firm's problem:

$$Max \quad W_0 = \sum_{t=0}^{\infty} \left(\prod_{j=0}^{t} (1+i_t)^{-1} \right) \left((1-\tau_{i,t}) \left(P_{i,t}(Y_{i,t}) Y_{i,t} - W_t L_{i,t} \right) - (1 - \kappa_{i,t} - \tau_{i,t}D_{i,t}) I_{i,t} \right)$$

subject to initial capital $K_{i,0}$, the production function, and capital accumulation. The first-order condition for labor yields the standard condition that the output elasticity is a markup $\mu_{i,t}$ over the share of payments to labor in total revenue, $s_{L_{i,t}}$ (see, e.g., Hall 1990):

$$1 - \alpha_i = \mu_{i,t} \frac{W_t L_{i,t}}{P_{i,t} Y_{i,t}} \equiv \mu_{i,t} s_{L_{i,t}}, \tag{1}$$

where $\mu_{i,t} = \left(1 + (\partial P_{i,t}/\partial Y_{i,t})(Y_{i,t}/P_{i,t})\right)^{-1}$. With perfect competition, price is not affected by the firm's output, so $\mu_{i,t} = 1$. Similarly, the Euler equation for capital implies that the output elasticity is a markup over the share of payments to capital in total revenue, $\alpha_i = \mu_{i,t}(R_{i,t}K_{i,t}) / (P_{i,t}Y_{i,t}) \equiv \mu_{i,t} s_{K_{i,t}}$, where capital's nominal cost is calculated with an implied rental rate or user cost of capital:

$$R_{i,t} = \frac{1}{1-\tau_{i,t}} \left((1+i_t)(1 - \kappa_{i,t-1} - \tau_{i,t-1}D_{i,t-1}) - (1-\delta)(1 - \kappa_{i,t} - \tau_{i,t}D_{i,t}) \right). \tag{2}$$

If $\kappa_{i,t-1} = \kappa_{i,t}$ and $\tau_{i,t-1}D_{i,t-1} = \tau_{i,t}D_{i,t}$, then the user cost takes the familiar Hall-Jorgenson

[2] With constant tax rates, this formulation is equivalent to allowing firms to deduct depreciation each period against income before paying taxes. $D_{i,t}$ is the present value of these deductions.

(1967) form:[3]

$$R_{i,t} = (i_t + \delta)\left(\frac{1 - \kappa_{i,t} - \tau_{i,t} D_{i,t}}{1 - \tau_{i,t}}\right) = (i_t + \delta)\, T_{i,t}, \tag{3}$$

where T_i is the wedge on the firm's user cost implied by changes in taxes, capital subsidies, and depreciation allowances.

The user cost is the implicit rental cost of using a dollar of capital for one period. It is thus capital's counterpart to the wage. The firm must earn an after-tax return to cover interest plus depreciation. All else equal, with a higher tax rate firms must earn a higher pre-tax return to compensate shareholders, raising the user cost. The purchase price of capital is effectively $1 - \kappa_{i,t} - \tau_{i,t} D_{i,t}$; hence, reducing investment subsidies or depreciation allowances also raises the user cost. We assume the subsidies and tax benefits are not externally observable.

Further, some firms have market power and charge a variable markup over marginal cost, $\mu_i > 1$, earning profits:

$$\Pi_{t,i} = P_{t,i} Y_{t,i} - R_{t,i} K_{t,i} - W_t L_{t,i}. \tag{4}$$

Hence, we define the profit share as $s_{\Pi t,i} = \Pi_{t,i} / \left(P_{t,i} Y_{t,i}\right) = 1 - s_{Lt,i} - s_{Kt,i} = \left(\mu_{t,i} - 1\right) / \mu_{t,i}$. Henceforth, when possible, we omit time subscripts.

2.2 Recovering Technology Growth

We now analyze how primal and dual TFP measurements can correctly capture sectoral technology growth in this environment. We start with the primal TFP calculation, which subtracts factor share weighted growth in inputs from real output growth. Differentiating the production function and substituting from the first-order conditions, we obtain:

$$\widehat{a}_i = \widehat{y}_i - \alpha_i \widehat{k}_i - (1 - \alpha_i)\,\widehat{l}_i, \tag{5}$$

where $\widehat{j} = dJ/J$ is the percent change of any variable J. Hence, if the primal TFP statistician obtained direct estimates of $\alpha_i = R_i K_i / (R_i K_i + W_i L_i)$, she could use this together with information on output, labor, and capital growth from the national accounts to correctly estimate technology growth in sector i.

[3] We abstract here from many of the rich considerations facing firms in their optimization decisions. Auerbach (1983) and Hassett and Hubbard (2002) survey the voluminous literature on the user cost. Personal taxes are also a source of capital taxes but do not directly impact growth-accounting as long as firms take the interest rate as given. We have abstracted from property taxes. These were unimportant in Korea and Hong Kong, and appear to have moved over time with corporate tax rates in Singapore and Taiwan; see Asher (1989) and Tanzi and Shome (1992).

Dual TFP calculations also require factor shares, but use them to weight growth of real factor prices, rather than factor stocks. Unlike factor stocks, which can be found or constructed using national accounting data, the dual statistician uses independent data not found in the national accounts in order to measure growth in the user cost ($\widehat{r}_{Dual}$) and wage ($\widehat{w}_{Dual}$). To relate the dual calculation to actual technology growth, we totally differentiate (4), substitute in the relation (5), and rearrange terms to get:

$$\widehat{a}_i = (1-\alpha_i)\left(\widehat{w}_i - \widehat{p}_i\right) + \alpha_i\left(\widehat{r}_i - \widehat{p}_i\right) + \frac{s_{\Pi_i}}{1-s_{\Pi_i}}\widehat{s}_{\Pi_i}, \tag{6}$$

where $\widehat{s}_{\Pi_i} = \widehat{\pi}_i - \widehat{p}_i - \widehat{y}_i$ is the profit-share growth rate for firm or sector i. Hence, if the dual TFP statistician obtained direct estimates of α_i, correctly measured factor price growth without errors by taking into account taxes, depreciation, and subsidies (i.e. $\widehat{r}_{Dual} = \widehat{r}_i$ and $\widehat{w}_{Dual} = \widehat{w}_i$), and had an accurate measure of both the level and growth in profit's share, she would correctly estimate technology growth.

Finally, we now relate aggregate TFP growth and technology growth to these sectoral values. We measure aggregate output as a Divisia index: $\widehat{y} \equiv \omega_F \widehat{y}_F + \omega_U \widehat{y}_U$, where the nominal output share of sector i is $\omega_i \equiv P_i Y_i / \left(P_F Y_F + P_U Y_U\right) \equiv P_i Y_i / PY$. This is the continuous-time analogue to discrete-time chain-weighting. Since the two firms have Cobb-Douglas production functions, we find:

$$\widehat{y} = \left(\omega_F \widehat{a}_F + \omega_U \widehat{a}_U\right) + \left(\omega_F \alpha_F \widehat{k}_F + \omega_U \alpha_U \widehat{k}_U\right) + \left(\omega_F\left(1-\alpha_F\right)\widehat{l}_F + \omega_U\left(1-\alpha_U\right)\widehat{l}_U\right).$$

The first term, $\widehat{a} \equiv \omega_F \widehat{a}_F + \omega_U \widehat{a}_U$, tells us how much aggregate output rises because of technological change, holding labor and capital in the two sectors fixed (so that the second and third terms are zero). Given this property, we define this term to be aggregate (i.e., average) technology change. If the sectoral TFP calculations were performed as specified in (5) or (6), one could combine those estimates with sector shares in output and correctly capture technology growth in this economy as $\widehat{a} = \omega_F TFP_F + \omega_U TFP_U$.

2.3 Pitfalls in Standard Growth Accounting Approaches

We now demonstrate how primal and dual TFP growth measures, as typically implemented in such an environment and subject to practical considerations such as data availability, relate to actual technology growth in each sector i. Standard primal TFP calculations are implemented with four pieces of information – growth rates in real output, capital stock, labor stock, and labor's share of output – as:

$$TFP_{Primal,i} \equiv \widehat{y}_i - (1 - s_{L_i})\,\widehat{k}_i - s_{L_i}\widehat{l}_i. \tag{7}$$

Note that rather than using factor shares in costs as the weights, primal TFP typically uses factor shares in output, information that is readily available from a country's national accounts. The share of payments to labor s_L is easiest to measure so the residual $(1 - s_L)$ is typically used to weight capital's share. If firms have market power and markups $\mu_i > 1$, the primal TFP calculation (7) does not equal technology change $\widehat{a}_i$. To show this, we again differentiate the production function and substitute from the first-order conditions to get:

$$\widehat{a}_i = TFP_{Primal,i} + (\mu_i - 1)\, s_{L_i}\left(\widehat{k}_i - \widehat{l}_i\right). \tag{8}$$

As in Hall (1990), equation (8) shows that using revenue shares in the context of profits can lead to a divergence between primal TFP growth and technology growth because weights on capital and labor do not properly capture marginal products. If capital grows faster than labor, a sector's technology growth exceeds measured primal TFP growth because the statistician overweights capital's productive contribution.

Now consider implementing the dual. Following Hsieh (2002), suppose the statistician continues to use labor's share in output and its complement as weights and assumes away the import of taxes, depreciation, and subsidies. She measures the user cost for all firms as the sum of the real interest rate and depreciation, $R_{Dual,i} = (i + \delta)$. This estimate differs from the firm's true user cost due to the tax adjustment term in equation (3), and so the statistician's implementation of the dual incorrectly estimates growth in this cost, $\widehat{r}_{Dual,i} = \widehat{r}_i - \widehat{t}_i$. This would clearly be the case, for instance, if the independent data on the user cost came entirely from market interest rates offered on bank loans. In such a case, it can be shown that:

$$\begin{aligned} TFP_{Dual,i} &\equiv (1 - s_{L_i})\,(\widehat{r}_{Dual,i} - \widehat{p}_i) - s_{L_i}\,(\widehat{w} - \widehat{p}_i) \\ &= \widehat{a}_i\,(1 - s_{\Pi_i}) - s_{\Pi_i}\widehat{\pi}_i - (1 - s_{\Pi_i})\,(1 - \alpha_i)\,\widehat{t}_i. \end{aligned} \tag{9}$$

With a zero profit share and no required tax adjustment, the dual captures technology correctly. If either of these conditions fails, it does not.

Finally, given the availability of primal and dual TFP estimates for the same country, one would like to characterize when they should equal each other. As a benchmark, suppose the dual statistician's independent data on factor prices is accurate (and fully takes account of taxes, depreciation, and subsidies), but does not distinguish economic profits in sector i from the return on capital. She would therefore measure $R_{Dual,i} = (P_i Y_i - WL_i)/K_i = (R_i + \Pi_i/K_i)$. Further, assume that the independent measure of wage growth is correct, i.e. $w_{Dual} = w$, and the statistician continues to use labor's share in output as the factor weight. To see the repercussion for the dual TFP measurement, we totally differentiate (4) and write:

$$\widehat{y_i} = s_{L_i}\widehat{l_i} + (1 - s_{L_i})\,\widehat{k_i} + s_{L_i}\,(\widehat{w} - \widehat{p_i}) + (1 - s_{L_i})\left((r_i \widehat{+ \pi_i}/k_i) - \widehat{p_i}\right). \tag{10}$$

It is easy to rearrange (10) to show that in this case, $TFP_{Dual,i} = TFP_{Primal,i}$, where the primal is calculated as in (7). This derivation is what drives the expectation that even when implemented with noisy data, dual TFP and primal TFP calculations should produce similar results. With economic profits, since the primal TFP calculation (7) does not equal technology, it is clear that dual TFP growth in this case will also not equal technology growth.

Finally, we relate these practical implementations of the sectoral TFP calculations – those in (7) and (9) – to actual aggregate technology in this two-sector economy. To fix ideas, imagine that the unfavored sector U has conditions under which primal and dual growth accounting avoid pitfalls in measuring technology growth. In particular, assume $\Pi_U = 0$, $\widehat{\pi}_U = 0$, $T_U = 1$, and $\widehat{t}_U = 0$. These conditions are violated, however, in the favored sector F. We assume the statistician is unaware of the two-sector nature of the economy, and so applies the aggregate factor shares in revenue as weights. With some algebraic manipulation shown in Appendix A, we can write primal aggregate TFP growth as:

$$TFP = \widehat{a} + s_{\Pi}\left(\widehat{x}_F - \widehat{k}\right) + \Sigma_K, \tag{11}$$

where $\widehat{x}_F = \alpha_F \widehat{k}_F + (1 - \alpha_F)\,\widehat{l}_F$ and $\Sigma_K = (K_F K_U)\,/\,(PYK)\,(R_F - R_U)\left(\widehat{k}_F - \widehat{k}_U\right)$. The second term of (11) captures the effect of favored firms' economic profits in creating a wedge between measured TFP growth and technology growth. The weights on inputs are shares in revenue rather than in cost and capital's share is measured as a residual, so the full profit share is allocated to capital. The third term, Σ_K, shows how reallocations of capital to sectors with higher user costs can lead TFP to outpace technology. Other things equal, a higher user cost implies a higher marginal product of capital and shifting capital to where it's more valuable raises output faster than share-weighted inputs. Such an analysis using the dual measure is omitted for brevity but yields the identical point: With significant and different distortions across sectors, estimating technology as distinct from TFP requires building from the bottom up.[4]

3 Profits and User-Cost Differences: Preliminary Evidence for Singapore

The model above suggests features of economies that can theoretically cause primal and dual TFP calculations to diverge from each other as well as from technology growth. This section details how in Singapore, the country with the most controversial TFP growth estimates, there is ample qualitative evidence that these features matter in practice. Virtually every description of Singapore's transition from a poor country in the 1960s to a rich, modern economy cites the government's active intervention and enticement of vast inflows of FDI. "Favored" firms – primarily government-linked corporations (GLCs), statutory boards (SBs), and multinationals – appeared to earn large profits, reflecting market power and favorable factor prices.[5] Incentives and favoritism, including tax preferences, increased over time.

3.1 Favored Firms Earned Large Economic Profits

GLCs (where the government is a substantial shareholder) and wholly-government-controlled SBs contributed as much as 25 percent of Singapore's GDP by the late 1980's.[6] Ermisch and Huff (1999) claim that government SBs earned monopoly profits in public utilities and telecommunications. The Singapore Economic Committee (1986) indicates that SBs enjoyed monopoly pricing, and the current surpluses of commercially-oriented SBs (included in national accounting profits) averaged 13 percent of GDP during 1975-1984 and 10 percent during 1985-1988. Ramirez and Tan (2003) report that listed GLCs have statistically significantly higher q-ratios than other listed firms.

Singapore's active enticement of FDI inflows also led to large profits. From 1972 to 1990, Singapore generated FDI inflows averaging almost 1/4 of gross fixed capital formation by offering a wide

[4] For example, using aggregate cost rather than revenue shares would not, in general, yield technology. Appendix A discusses this further.

[5] SBs are created by acts of Parliament and are accountable to particular ministries. For example, SBs provided utility services, telecom, and port operations. GLCs are incorporated under the Companies Act. Several state holding companies (e.g., Temasek) hold equity on behalf of the government; Singapore's Economic Development Board sometimes takes equity stakes, as well. See Ramirez and Tan (2003) and Economist Intelligence Unit (2004).

[6] Late 1980s share is from IMF (1995). Department of Statistics (2001) argues that by the mid-90s, the GLC share of GDP was only a bit over 10 percent, though calculation explicitly excludes widespread holdings in companies where the government owns less than 20 percent of the company. Ramirez and Tan (2003) point out that Singapore Statistics' definition of GLCs exclude many companies in which the government has effective control.

range of incentives that reduced production costs. Singapore figures prominently in the literature on tax havens: "low-tax jurisdictions that provide investors opportunities for tax avoidance" (Desai, Foley, and Hines, 2006). Firms might locate intangible assets in Singapore or else adjust internal transfer prices to realize high profits there. Indeed, the average tax rate for U.S. multinationals in Singapore is consistently among the lowest in the world – about 30 percentage points below the unweighted mean in 1983, for example. Such profit shifting, as well as other subsidies that reduced operating costs, would lead to large economic profits.

3.2 Capital Subsidies

GLCs, SBs, and multinationals also had user costs of capital that likely differed from other firms. Special treatment (investment subsidies in our model) included direct government financing, implicit debt guarantees, and political connections.[7] A major benefit was subsidized land access. Under the Land Acquisition Act, the government had authority to purchase land at its 1973 market price, which it leased to industrialists at rates that reflected the low acquisition price. As land prices rose, the value of the land subsidy grew more valuable.[8] Favored firms also received government directed credit. In the 1970s, government loans to foreign investors, GLCs, and commercially-oriented SBs amounted to about 20 percent of the total stock of bank loans to the private sector (these figures exclude sizeable housing loans). The average interest rate on these government-directed commercial loans was about 3 percent less than the bank-lending rate used in Hsieh (2002) to implement a dual TFP calculation. (In the 1980s, the government stopped publishing the interest rate information.)

3.3 Preferential Tax Treatment

Preferential tax policy toward some firms was a significant source of heterogeneity in the user cost of capital. Major legislative changes took place under the Economic Expansion Incentives (Relief from Income Tax) Act. The 1967 Act (as amended in 1970) gave so-called "pioneer firms" a five-year tax holiday, i.e., a tax rate of zero. In 1975, the tax-holiday period was extended to 10 years. In 1984, pioneer status was extended to selected service firms. In 1987, Singapore reduced the tax rate for

[7] The Economist Intelligence Unit (1993) states: "Singapore's government relies heavily on incentives to attract foreign investment ... Investment incentives include tax holidays and concessions, accelerated depreciation schemes, favourable loan conditions, equity participation and high-quality industrial estates..." Burton (1995) claims that GLCs' "costs of capital are usually lower than for companies in the private sector." U.S. Embassy (2001) notes that "GLCs were given preferential rates by DBS Bank, itself a GLC."

[8] Ermisch and Huff (1999) and Tan (2001) discuss the implicit land subsidy. In Schein's (1996) case studies, negotiations between the government and foreign investors over leases for favorable land parcels figure prominently.

firms ending their tax-holiday period from 40 percent to 10 percent. The share of manufacturing value added accounted for by pioneer firms rose from an average of 53 percent in the first half of the 1970s to about 64 percent in the second half of the 1980s. More generally, depreciation provisions became more generous after 1979, and the statutory corporate tax rate fell from 40 percent to 33 percent in 1986 and to 32 percent in 1989.[9] Data on changes in the tax code also confirm a meaningful quantitative role for the tax adjustment in the growth accounting exercises. Figure 1A shows the statutory rate and two measures of taxes relative to income from Inland Revenue Authority Reports and from financial reports of corporations.[10] The three measures all decline in the 1980s.

4 Quantifying Technology Growth in the Asian Tigers

We now turn to quantifying these imperfections to allow us to use the expressions derived in Section 2 to generate our preferred measure of technology growth. We analyze Singapore in most detail, but also quantify several terms for Hong Kong, Korea, and Taiwan. We do this to facilitate a mapping of our results to the existing literature but also to corroborate our methodology for countries which may lack the imperfections we have highlighted in Singapore. We start with a measurement of economic profits for all of the NIEs and then perform a detailed calibration of the Singaporean growth experience to report our preferred sectoral and aggregate technology growth estimates.

4.1 Measuring the Economic Distortions

Table 2 shows the level and change in $(1 - s_L)$ for Singapore, Hong Kong, Korea, and Taiwan, as measured in their national accounts and as used by Young (1995) and Hsieh (2002). As we've argued above, capital's share of costs may be distorted in residual capital payments $(1-s_L)$ because the latter includes any pure profits. To address this, we estimate factor shares in cost in the NIEs and compare these shares with factor shares of revenue reported in the growth accounting studies. We start by combining international data on industry capital-cost shares from Sarel (1997) with data on the industry mix of output to calculate "true" capital shares in *cost*, α. Table 2, line 3, shows this estimate for α in each of the NIEs.

One might worry that if the NIEs had different product mixes within one-digit industries than

[9] Sources for this paragraph are Fordham (1992), Commerce Clearing House (various dates), Low et al. (1993), and http://www.iras.gov.sg/ESVPortal/ct/ct_b.2.2_what+are+the+tax+rates.asp (downloaded May 17, 2006).

[10] Appendix B details our construction of these series.

the world norm, our calculation might be misleading. To check if this is important for Singapore, we obtained two-digit-manufacturing value-added data for 1990 and applied factor shares (averaged 1980-1996) from Dale Jorgenson's U.S. data. The implied manufacturing capital share was 0.32, compared with 0.31 in Sarel. Product mix thus cannot explain much of a gap between $(1 - s_L)$ and α.[11]

We now use the implied cost shares to calibrate the role of profits. Table 2 quantifies profit shares s_Π by comparing estimated revenue shares (line 1) with estimated cost shares (line 3). In essence, we assume that any difference between capital's share of costs in our calculation, α, and residual capital payments in the growth accounting studies, $(1 - s_L)$, is attributable to economic profits. If capital's share in total cost is α and labor's share is $(1 - \alpha)$, then the profit rate is $s_\Pi = ((1 - s_L) - \alpha) / (1 - \alpha)$.[12]

Section 3 argued qualitatively that in Singapore, government policy gave some firms market power, low average factor prices, and large profits. Indeed, Singapore's strikingly low labor share is consistent with this anecdotal evidence and in Table 2, Singapore is the only country with substantial profits. The residual revenue share $(1 - s_L)$ is about 1/2, but our estimated capital cost share is only a bit above 1/3 (line 3), implying a profit share of about 1/4 (line 7). As line 8 shows, this large profit share declined about 1.2 percent per year from 1970-1990.

Estimated profits in Taiwan, though small, were negative. The high labor share estimate (3/4) drives this. Young (2003) argues that a labor share of 3/4 overstates the true share: Young (1995) inadvertently overcorrects for (imputed) proprietor's wage income. Thus, we interpret these results for Taiwan (as well as for Korea and Hong Kong) as indicating small pure profits.

Anecdotal evidence suggests large pure profits in Singapore. But profits of 1/4 of GDP are exceptional. Obviously, these calculations reflect measurements claiming that Singapore's labor's share was about one half. Appendix B discusses and defends this figure. Further, we now corroborate the magnitude of profits with a back-of-the-envelope estimate. Following Rotemberg and Woodford (1995), we use factor shares and the capital-output ratio to back out an implied return to capital including profits. From 1970-1990, the nominal ratio of tangible capital to GDP averaged 2.38; in the mid-to-late 1980s, it was nearly 3. The average depreciation rate δ in Singapore appears relatively flat at 6.7 percent. Thus, $(i + \Pi/K + \delta)\,(qK) \,/\, (PY) = (i + \Pi/K + 6.7)\,(2.38) = s_K + s_\Pi = 0.484$.

[11] Additionally, one might worry about our assumption of constant one-digit factor shares. But deviations from strict Cobb-Douglas appear small relative to mean differences across industries. This is true in Jorgenson's U.S. data, for example.

[12] This calculation assumes an even distribution of profits across sectors. In Section 4.2, we will assume profits exist only in the relatively capital-intensive favored sector, and this will slightly increase the profit share.

The implied value of $(i + \Pi/K)$ is 14 percent – substantially in excess of the corresponding U.S. rate of 6 percent.

Rotemberg and Woodford argue that 6 percent is the U.S. required return to capital, including an equity premium, and implies little if any pure profit. But if, because of capital mobility, Singapore's interest rate were similar to the U.S. rate, then the 'excess' return of 8 percent represents profits. Multiplying an 8 percent excess return by the capital-output ratio again suggests a rate of profit of close to 20 percent.[13]

Industry estimates also suggest very large profits. Kee (2002) estimates markups and returns to scale for manufacturing industries as in Hall (1990). He finds that most industries have large markups of price over marginal cost; but few have correspondingly large increasing returns, implying very large profits. Indeed, in a pooled specification, Kee's estimates imply that pure profits exceed 50 percent (!) of value-added.[14]

Next, we try to quantify the tax, subsidy, and depreciation term for the unfavored sector $\widehat{t_u}$ because it drives a wedge between $\widehat{r}_{Dual}$ and the actual change in unfavored user costs $\widehat{r_U}$. We only need to do this for the unfavored sector because we will be using the dual to measured unfavored sector TFP growth but using the primal to measure favored sector TFP growth. Using the data in Figure 1a (discussed in Appendix B), we calculate the unfavored tax wedge $T_u = (1 - \tau_U D_U) / (1 - \tau_U)$ under the assumption there are no unobserved subsidies in the unfavored sector. In addition to data on tax rates, we also need the present value of depreciation allowances, D_U. We use the tax code to calculate D for each major type of business capital. For domestic non-manufacturers, the capital-income weighted present value of depreciation allowances rose from about 0.6 before 1977 to about 0.75 after 1979. The major changes over the 1970-90 period are (i) in 1978, initial and annual allowances for industrial buildings become more generous; and (ii) in 1980, allowances for transport and machinery become more generous. The tax code has numerous other special provisions for targeted activities, though most are quantitatively modest. In all, we calculate that the tax wedge for firms paying the statutory rate fell 0.7 percent per year, i.e. $\widehat{t_u} = -0.7$.

[13] Studies for other countries also sometimes suggest that product market distortions lead to substantial economic rents. Blanchard and Giavazzi (2003) discuss the sharp decline in labor's income share in many European economies from the early 1980s to the mid-1990s. Consider Italy, where labor's share fell from almost 80 to about 60 percent. They attribute the decline to a reduction in labor's ability to capture the rents arising from product market restrictions. For such a large shift in rents to occur, the rents themselves must be large—e.g., for Italy, on the order of 15 to 20 percent of GDP.

[14] If μ is $P/(MC)$ and γ is the returns to scale parameter, then $\Pi/(PY) = (\mu - \gamma)/\mu$. See, e.g., Basu and Fernald (2001).

4.2 Quantifying Technology Growth

We now assess technology change in Singapore. As a by-product, we describe how the two sectors and the aggregate economy evolved. We assume profits and unmeasurable subsidies or tax treatment are important, but only in the favored sector. In particular, we assume $\Pi_U = \widehat{\pi}_U = 0$, $\Pi_F = \widehat{\pi}_F \neq 0$, and $\widehat{t}_F$ is unobservable and not equal to zero. These assumptions allow us to derive information from the original growth accounting results of Young (1995) and Hsieh (2002). We combine this information with our measurements of Singapore's market imperfections and the relations derived in Section 2 to offer our preferred measures of sectoral and aggregate technology growth.

Consistent with the anecdotal evidence from Section 3, we define the favored sector as the following 1-digit SIC industries: Manufacturing, Finance, Utilities, and Transport. The unfavored sector is the remaining sectors: Agriculture and Fishing, Quarrying, Construction, Commerce, and Other Services. With this classification, $\widehat{y}_F$ averages 9.6 percent from 1970-90; $\widehat{y}_U$ averages 6.1 percent. On average, the favored sectors account for 59 percent of output. Unfavored prices rise 0.1 percentage point per year faster than overall prices; favored prices rise 0.1 slower (all deflators are Tornquist indices).

We start with technology measurement in the unfavored sector. When the profit share equals zero and user cost is measured correctly, dual TFP growth (6) equals sectoral technology growth. Hence, to implement this calculation, we simply need capital's share (α_U), the relative-price growth ($\widehat{p}_U$), nominal wage growth ($\widehat{w}$), and unfavored user-cost growth ($\widehat{r}_U$). We assume that wages are the same in both sectors, and so take Young's estimate of aggregate nominal wage growth. As we will discuss in greater detail below, we believe our arguments in Section 2.3 that dual statisticians are likely to miss profits, subsidies, and preferential taxes apply to measurements in Hsieh (2002). Hence, we use his results on real growth in the capital cost to back out nominal growth in the unfavored cost of capital, i.e. $\widehat{r}_{Dual} = \widehat{r}_{Hsieh} + \widehat{p} - \widehat{t}_U$.

As in Section 4.1, we use one-digit international factor shares to estimate cost shares. Unfavored industries are labor intensive: average α_U is 19 percent. Favored industries have a much higher α_F equal to 42 percent. We estimate these shares every period; but they are very close to constant over time. After making several adjustments detailed in the footnote below, we now estimate unfavored technology (does not add up exactly due to rounding):[15]

$$\begin{aligned}\widehat{a}_U &= (1-\alpha_U)(\widehat{w}-\widehat{p}) + \alpha_U\left(\widehat{r}_{Hsieh} - \widehat{t}_u - \widehat{p}\right) + (\widehat{p}-\widehat{p}_U) \\ &= (0.81)(2.1) + (0.19)(-0.1) + (-0.1) = 1.5 \text{ percent.}\end{aligned}$$

This is similar to Hsieh's original dual estimate for the overall economy. The key differences in our calculation are that we use sectoral labor shares, use Young's wage data, make a correction for the impact of tax changes and depreciation allowances, and measure real factor prices in terms of sectoral, not aggregate, deflators. Had Hsieh calculated dual TFP using Young's wage series and using sectoral labor shares, he would have estimated TFP growth of 1.0 percent per year. [CHECK] Hence, technology growth in the unfavored sector is actually higher than Hsieh's comparable dual estimate because of the higher weight on faster-rising wages.

Measuring favored technology growth, $\widehat{a}_F$, and aggregate technology growth, $\widehat{a} \equiv \omega_F\widehat{a}_F + \omega_U\widehat{a}_U$, requires further assumptions and additional data. To use the cost-based primal (5) to determine technology growth in the favored sector, we need $\widehat{y}_F$, α_F, $\widehat{k}_F$, and $\widehat{l}_F$. The sectoral data give us $\widehat{y}_F$, $(\widehat{p}-\widehat{p}_F)$, and α_F, which we either use on their own or in the calculation for favored-sector labor growth: $\widehat{l}_F = \widehat{s}_{L_F} + \widehat{y}_F + (\widehat{p}-\widehat{p}_F) - (\widehat{w}-\widehat{p})$. We additionally get s_{L_F} and $\widehat{s}_{L_F}$ from the identity $s_L = \omega_F s_{L_F} + \omega_U s_{L_U}$: Young's data give us the aggregate s_L, the output data give us the weights, and the international cost share data give us $s_{L_U} = 1-\alpha_U$. Thus, we can back out an estimated time series for s_{L_F}, which averages 31 percent, and for $\widehat{s}_{L_F}$, which averages 2.9 percent per year. Together, these estimates imply that $\widehat{l}_F$ is 10.4 percent per year.

This leaves only favored-sector capital growth $\widehat{k}_F$. We cannot simply use the relationship: $\widehat{k}_F = \widehat{s}_K + \widehat{y}_F + (\widehat{p}-\widehat{p}_F) - (\widehat{r_F}-\widehat{p})$ because we do not know $\widehat{r}_F$. Given aggregate $\widehat{k} = 11.0$ and $\widehat{k}_U = 6.0$, plus the relationship $\widehat{k} = \beta\widehat{k}_F + (1-\beta)\widehat{k}_U$, we can obtain $\widehat{k}_F$ for any value of $\beta = K_F/K_U$. We obtain a benchmark by defining the user-cost ratio $\eta = R_F/R_U < 1$, and using the relationship:

$$\eta\beta = \frac{R_F K_F}{R_U K_U} = \frac{s_{K_F}}{s_{K_U}}\frac{\omega_F}{\omega_U} = \frac{0.23}{0.19}\frac{0.59}{0.41} \approx 1.75. \tag{12}$$

[15] First, our industry breakdown omits imputed bank services, which we cannot allocate. As a result, aggregate industry output grows 0.3 pp per year faster than Young's expenditure-side measure from 1970-90. This immediately translates into 0.3 pp faster growth in the primal's aggregate real wage. It does not, however, affect the GDP deflator, so it leaves the dual estimates unchanged. Second, we need to choose whether to use the primal or dual measure of wage growth. We use Young's primal measure; with the 0.3 pp adjustment, the aggregate real wage rises by 2.1 percent per year. We average two of Hsieh's three cost of capital measure because, as we discuss in Section 5, we feel ROE is problematic as a measure of the real user cost. This raises average dual user cost growth by about 0.3 percent. We adjust for the fact that the measures cover different time periods. On balance, our estimate of $(\widehat{r}_{Dual}-\widehat{p})$ is -0.1 percent – qualitatively similar to the original estimate of 0.3 percent.

Estimates in Hsieh (2002) show R_U around 20 percent. As Sections 3 and 4 discuss, preferential tax treatment and subsidized capital plausibly reduced this cost by about 5 percentage points for the favored sector. Hence, we calibrate $\eta \approx 0.75$ and find $\beta = K_F/K_U \approx 2.3$ and $\widehat{k}_F = \left(\widehat{k} - (1-\beta)\,\widehat{k}_U\right)/\beta = 13.1$ percent.[16] These estimates imply that technology growth in the favored sector was abysmal: -2.0 percent per year.[17]

Aggregate technology is $\widehat{a} = \omega_U \widehat{a}_U + \omega_F \widehat{a}_F$. Column 1 of Table 3 shows that with $\widehat{a}_F = -2.0$, $\widehat{a}_U = 1.5$, and $\omega_F = 0.59$, we find $\widehat{a}$ is -0.5 percent per year.

What key assumptions and features of the data drive these estimates? In the unfavored sector, constant returns and perfect competition are crucial, since they allow us to use the dual approach. These assumptions seem reasonable, given standard "replicability" arguments for constant returns combined with competition. In the favored sector, we have used accounting decompositions (but not constant returns) to derive factor-quantity growth. The strong growth in $\widehat{l}_F$ is driven by the increases in favored labor's share, i.e., by $\widehat{s}_{L_F}$. Those increases are driven by the declining profit rate – which, in turn, is driven in the data by the constant aggregate labor share combined with the shift towards capital-intensive sectors. These are robust features of the data. Strong growth in $\widehat{k}_F$ is driven by the large gap between strong observed aggregate capital growth and weak estimated growth in $\widehat{k}_U$ (which is driven by the flat user cost).

Given the underlying forces in the data that drive the estimates, our quantitative and qualitative results are not particularly sensitive to the assumptions we have made (see Table 3). Increasing the mean ratio of favored to unfavored capital (K_F/K_U) necessarily reduces favored capital's growth rate ($\widehat{k}_F$) which slightly improves favored technology ($\widehat{a}_F$). As mentioned above, we drop the ROE data – one of Hsieh's three proxies for the user-cost – in our baseline measurement for the unfavored cost of capital. If instead we include the ROE user-cost measure, it reduces $\widehat{a}_U$ negligibly, since the capital-weight is small; it slightly improves $\widehat{a}_F$ (because it raises $\widehat{k}_U$ and reduces $\widehat{k}_F$). Our results are also robust to arbitrary reductions of the estimated profit shares. Two methods of implementing

[16] Another condition implied by our model is $\widehat{r} + \widehat{k} = (1/(\eta\beta+1))\left(\widehat{r}_U + \widehat{k}_U\right) + (\eta\beta/(\eta\beta+1))\left(\widehat{r}_F + \widehat{k}_F\right)$. The calibration in the text identifies all pieces other than $\eta\beta$. This equation need not and does not yield the same value as (12) – our calibration is, loosely speaking, overidentified. But the two estimates (1.5 versus 1.75 in the text) are close. In essence, our story is not consistent with any arbitrary sectoral definitions. Placing manufacturing in the unfavored sector, for example, would yield a very large discrepancy between the estimates. Our allocation relied on qualitative evidence alone and allocates each industry entirely into one sector or the other, so the small difference corroborates our calibration. In addition, we verified that equations hold for each sector and that (11) holds in the aggregate. (We used a time-varying profits term in (6); other equations do not appear sensitive to using a first-order approximation, but with large declines in the profit share over time, the approximation is less exact.) Further detail on levels and growth rates of key variables in the benchmark calibration is available upon request.

[17] These results are in part corroborated by Young's finding that technology growth in the manufacturing sector was even worse than that for the aggregate economy.

this – increasing Sarel's (1997) measures of capital's share in costs by 9 percentage points in each sector and increasing the growth-accounting labor share by 8 percentage points each year – each halve the average profit share, but increase its rate of decline. As such, the baseline results do not change significantly.

Technology estimates are, however, sensitive to assuming constant returns in the favored sector. Measured technology would improve if returns to scale were sharply decreasing, but decreasing returns would not necessarily imply a more optimistic assessment of Singapore's performance. Suppose each firm has a fixed cost F and increasing marginal cost: $Y = X^{\rho} - F$, where X is a composite input, $\rho < 1$, and $\gamma = d\ln Y/d\ln X = \rho\,(1 + F/Y)$ denotes returns to scale (so $\gamma < 1$ implies decreasing returns). The competitive equilibrium, where $MC = AC$, has constant returns to scale ($\gamma = 1$). Government-supported entry barriers shift the firm's demand curve up as well as making it less elastic. If the upward shift dominates the reduced elasticity, then each firm produces more, which pushes $\gamma < 1$. Subsidies to input use also lead firms to overproduce and push down γ. Thus, in this model, government interventions reduce the efficiency of the economy even if true technology does not change.[18] Hence, Singapore's heavy interventions could have led to falling TFP (and reduced our measured technology) even if it favored high-productivity firms.

Nevertheless, industry estimates for other countries generally suggest constant or increasing returns (e.g., Basu and Fernald, 2001, and Inklaar, 2007), and we believe constant returns is the right benchmark. The qualitative conclusion is that while some sectors performed well, overall technology growth in Singapore was singularly unimpressive.

5 Reconciling Empirical Puzzles Regarding Growth in Asia

Finally, we apply our framework and quantification of market imperfections to reconcile important empirical puzzles related to the rapid development of the NIEs. We start with the most prominent puzzle, the gap between dual and primal TFP in Singapore and discuss the lack of gap for other NIEs. We then note how our quantification of profit shares in the NIEs reconciles a key implication of trade-based explanations of Asia's rapid development that previously contradicted the data.

[18] Similarly, Restuccia and Rogerson (2004) offer a story in which firms have decreasing returns (e.g., from limited managerial span of control) but differ in productivity levels. Shifting resources away from the undistorted equilibrium—whether towards or away from high-productivity firms—reduces overall TFP and welfare.

5.1 Understanding Gaps in Singapore's TFP Growth Calculations

The above calculations implicitly assume that differences in previous primal and dual measurements of Singapore's TFP reflect the types of imperfections included in our model economy. We now show the extent to which our explanation can quantitatively reconcile the gap between Hsieh's dual and Young's primal TFP results, a highly controversial and unresolved puzzle in the literature. Manipulating equation (10) for the aggregate economy, one can express the difference between typical implementations of the dual and primal as:

$$TFP_{Dual} - TFP_{Primal} = s_L \left(\widehat{w}_{Dual} - \widehat{w}\right) + (1 - s_L) \left(\widehat{r}_{Dual} - (\widehat{r + \pi/k})\right). \tag{13}$$

As discussed above, if both use the same weights, the primal and dual differ if growth in either estimated wages or capital-payments differ.

Table 4 gives this decomposition for all the NIEs with data from Young (1995, 1998) and Hsieh (2002). Lines 1 to 3 show the items on the right side of equation (13); lines 4a and 4b show primal and dual TFP growth. Lines 5 and 6, respectively, show the contribution of wages and capital payments to the dual-primal difference. Primal and dual TFP differed markedly only in Singapore and Taiwan. Wages play a sizeable role in Singapore and account for the bulk of the difference in Taiwan. Hsieh (2002) has little discussion of the role of wages.[19] We view the wage discrepancies as largely a measurement issue. We focus only on capital's contribution (line 6) because the imperfections we focus on only impact the second term in (13). In Singapore, this term accounts for the bulk of the dual-primal gap. Again, the puzzle is that weak primal TFP performance implies sharp declines in capital returns, but estimated user costs are flat.

We assume $\widehat{w}_{Dual} = \widehat{w}$, $\widehat{r}_{Dual} = \widehat{r} - \widehat{t}$, and re-write (13) as (CHECK):

$$TFP_{Dual} - TFP_{Primal} = s_{\Pi} \left(\widehat{r} + \widehat{k} - \widehat{\pi}\right) - (1 - s_L)\,\widehat{t}. \tag{14}$$

The first term shows the impact of the time-varying economic profits, which impacts the primal

[19] The two use slightly different source data on wages and employment. Young measures $\widehat{l} = \sum s_j \widehat{l}_j$. He benchmarks to total labor compensation, which imposes the identity that $WL = \sum W_j L_j$. Hence, his estimate of implicit wage growth, $\widehat{w}_{Primal} = \widehat{w} + \widehat{l} - \sum s_j \widehat{l}_j$, is necessarily consistent with the aggregate compensation figures. Hsieh measures $\widehat{w}_{Dual} = \sum s_j \widehat{l}_j$ directly, so he doesn't need to benchmark to aggregate compensation. Implicitly, two factors "explain" the wage differences. First, Hsieh's survey data have less growth in employment than the official tabulations and he implicitly has less labor quality growth than Young (1995); for given growth in nominal compensation, these factors imply faster wage growth. Second, Hsieh's figures on total labor compensation rise from 25 percent of GDP in 1973 to 37 percent of GDP in 1990. Hence, his show larger growth in nominal labor compensation. Young (1998) questions the reliability of Hsieh's wage data.

calculation by distorting the factor share weights. The second term shows how the dual and primal may differ because growth in the taxes, depreciation treatment, or subsidies are implicitly captured by the primal but not by the dual. In order to calculate $\widehat{t}$ for the overall economy, we need to complement the data we had for unfavored firms, with data on the tax rates and depreciation allowances for the rest of the economy. Figure 1B shows that foreign manufacturing firms, who were major recipients of "pioneer" status, paid lower rates, which fell from about 40 percent to under 10 percent by 1990. Other firms' rates fell only to about 30 percent. Foreign manufacturing accounted for about 1/3 of total corporate profits and 2/3 of foreign profits in the 1980s. We use the average tax rate for foreign manufacturing, assume that other firms paid the statutory tax rate, and calculate the overall tax wedges as described for the unfavored firms in Section 4.2. One significant difference for favored firms was a 50 percent investment allowance introduced in 1980 for non-pioneer-manufacturing, which was *in addition* to other, regular allowances. We assume that 40 percent of foreign manufacturing firms received the investment allowance, based on the roughly 60 percent share of manufacturing production accounted for by pioneer firms. We use net fixed asset data to weight our calculation that the tax wedge declined 1.3 percent per year for foreign manufacturing and our earlier result that it declined 0.7 percent for firms paying the statutory rate ($\widehat{t}_u = -0.7$). As shown in Table 5, these tax adjustments imply an aggregate tax wedge of -0.9 ($\widehat{t} = -0.9$), which accounts for 0.4 percentage point of the gap in dual and primal results ($(1 - s_L)\,\widehat{t} = -0.4$).[20]

Table 6 uses equation (14) to decompose Singapore's dual-primal gap. Capital contributed 1.6 percentage-points per year to the gap (line 4). The profit term in (14), $s_\Pi \left(\widehat{r} + \widehat{k} - \widehat{\pi}\right) = s_\Pi \left((\widehat{r} - \widehat{p}) + \left(\widehat{k} - \widehat{y}\right) - \widehat{s}_\pi\right)$ accounts for about half the gap (line 1). The profit share was high but declining, and the capital-output ratio was rising. Together with the contribution of the tax wedge (line 3), this leaves the residual of 0.3 percent per year (line 2). Under the null that the primal and dual are accurate, the residual reflects user-cost heterogeneity unrelated to taxes, such as favorable access to land and financing, and other unobserved subsidies. Hence, while both distortions (as

[20] Although the decline in statutory rates was smaller than the decline in foreign manufacturing rates, the decline in T_i was still large for non-foreign manufacturing because of the increase in D. The overall tax wedge is the capital-weighted average of the two wedges. Based on net fixed asset data in Singapore Statistics (1992b), we use 1/4 as our benchmark for the weight of foreign manufacturing and find that T falls at 0.9 percent per year. We estimate the trend in the tax wedge for each type of capital, and then weight by average capital-income shares. Following Hsieh (2002), we fit a time trend to the data and divide by the mean. One can apply this procedure to data that might occasionally take on negative values, so that one cannot use logs. But taking logs first gives similar results. This calculation is fairly robust to alternative paths for the capital weight. We also confirmed that qualitative results were robust to a wide range of assumptions about depreciation allowances. Note that the declining tax wedge is consistent with a rising corporate tax-to-GDP ratio because (corporate profits/GDP) was rising.

well as taxes) drive a wedge between the primal and the dual, profits are quantitatively the most important.

As discussed above and in Appendix B, these calculations take seriously that Singapore's labor's share was about one half. However, even if we arbitrarily raised labor's share in revenue to 0.6 in all periods, profits would still explain a gap of 0.5 percentage point per year. Alternatively, if we arbitrarily halved the profit share by raising our estimate of α by 8.5 percentage points, profits would still explain a gap of 0.7 percentage point. In both cases, although s_{Π} would be much smaller, $\widehat{s}_{\Pi}$ would also be much more negative. Hence, these calculations appear robust.

This reconciliation of Hsieh's dual with Young's primal calculation requires that Hsieh's cost of capital measure captures the user cost for the unfavored sector only and excludes profits. Why is this a reasonable assumption? Hsieh uses three rate-of-return measures are used in Singapore's dual calculation: The earnings-to-price ratio (E/P); an average lending rate; and the return on equity (ROE). All omit subsidies and taxes, and two of the three omit profits.

First, consider the earnings-price ratio. Many of the companies receiving preferential treatment did not require private-sector financing via the stock exchange. Nonetheless, a standard formula (e.g., Brealey and Myers, 1996) says that a company's share price is $P_i = E_i/i_i + PVGO_i$ – the value of a perpetuity yielding E_i, plus the present value of growth opportunities – implying that $E_i/P_i = i_i - i_i\,(PVGO_i/P_i)$. Hsieh implicitly assumes we can ignore the second term. With perfect capital mobility, this measure i_i is the expected return for the global representative investor, which might be appropriate for a firm seeking private–sector financing. So even if exchange-listed companies earn large pure profits, this is unlikely to impact the E/P ratio because they not only have higher earnings but also have higher prices.

Second, the average bank lending rate is also more appropriate for unfavored firms. Young (1998) describes how a heavily regulated "cartel arrangement" kept lending rates above competitive levels. But GLCs, SBs, and multinationals generally had alternative, likely cheaper sources of funding, including government loans, FDI, and international lending. In the 1980s, for example, only 21 percent of Singapore bank loans to non-bank customers went to heavily favored manufacturing, transport, and communications industries – which accounted for 40 percent of GDP. FDI was a much more important funding source for these firms. Further, to the extent some firms that earned large profits did borrow at published rates from banks, the realization of their profits would not impact the average lending rate.

Finally, the dual uses return on equity from Singapore's Registry of Companies and Businesses.

ROE is the ratio of two easily manipulated elements in firm financial statements; it is an accounting – not a market – measure. Firms have considerable discretion in reporting intangible assets such as goodwill or brand name, which in turn affects the book value of shareholder equity; firms earning large profits seem particularly likely to report sizeable intangible assets. From 1980-90, the underlying asset figures for non-financial firms alone show a ratio to GDP that averages 4.5 – compared with a capital-output ratio of 2.8 in the national accounts. In sum, we view the ROE figures as a much less reliable measure of the opportunity cost of funds than the E/P ratio or the average lending rate, both of which correspond primarily to the unfavored sector.

Our interpretation of the dual-primal divergence is more plausible than the main alternatives. First, Hsieh suggests, with little evidence, that there were massive national accounting errors. We discuss this hypothesis (and its difficulties) in Appendix C. Second, Young dismisses the dual calculations, in part because they ignore key tax benefits and are not appropriate for all firms. We agree that these issues are central, but find the pattern of mismeasurement economically important. The two methods differ because a subset of the economy earned very large and declining profits and received government favoritism that grew over time.[21]

5.2 Why the Dual and Primal Calculations are Consistent in the Other NIEs

In Singapore, large but declining profits and heterogeneous costs of capital, reflecting government intervention, created the large dual-primal TFP gap. How did these factors play out in the other NIEs? Tax effects were smaller outside of Singapore; and profits and heterogeneity appear relatively unimportant in less-interventionist Hong Kong. But Taiwan and Korea also intervened heavily. Why is the gap so much smaller in Taiwan? Why isn't there a gap in Korea?

For Taiwan, Wade (1990) documents the considerable government intervention, especially for large-scale firms in favored sectors. Government intervention, however, does not inevitably lead to high profits – Singapore is the exception to world experience, not the rule. Estimated profits in Taiwan were small.[22] Hence, we attribute most if not all of capital's contribution to Taiwan's dual-primal gap as reflecting capital-cost heterogeneity, consistent with the anecdotal evidence of heterogeneity.

Korea also intervened, but the evidence suggests it did so without creating large profits or

[21] See also Feenstra and Reinsdorf (2003) and Barro (1999) for additional possible interpretations of the dual-primal discrepancy and the implications for national accounts.

[22] For Taiwan, Hong Kong, and Korea, the estimated contribution of profits from equation (14) is small.

heterogeneity in the *growth rates* of the cost of capital.[23] First, our estimates, as well as Leipziger's (1988) and Kihwan and Leipziger's (1997) firm-level studies, suggest small profits. Second, Korea's transition also had heterogeneous costs of capital, but these different costs appeared to grow at similar rates. The different *levels* of capital cost that Hsieh documents in Korea, that of the curb loan rate (the market rate) and the discount rate (the "preferred" rate), move roughly in tandem.[24]

In addition, while FDI played a huge role in Singapore's development, it had negligible impact on Korea in the 1970's and 1980's. IFS statistics confirm that by 1990, FDI amounted to nearly half of investment in Singapore but only 1 percent of investment in Korea. As such, the idiosyncratic, one-time benefits offered to entice FDI and leading to large profits and subsidies in Singapore had less scope to impact growth accounting in Korea.

Finally, we offer novel and direct evidence that wedges in the cost of capital due to tax treatment were far less important in the other NIEs. Table 5 shows that the equivalent tax adjustments (the first term from (14)) for the other NIEs appear much smaller than in Singapore. For Taiwan, the contribution is about 0.2 percentage point per year, largely reflecting increases in investment tax credits (κ) in the 1980s. In Korea, the tax wedge contributes about 0.1 percentage point. Tax rates for large companies fell over time, and depreciation allowances became somewhat more generous. But κ (for selected investments) also became less generous. In Hong Kong, the change in the tax wedge contributes nothing to the dual-primal gap: Depreciation allowances became slightly more generous over time, but the corporate tax rate also rose slightly.

In sum, there are many similarities in the broad development strategies of Singapore, Taiwan, and Korea. But the lack of profits and similar growth rates in favored and unfavored costs of capital resulted in relatively consistent dual and primal TFP estimates outside of Singapore.

5.3 The Role of Trade and Export-Led Growth

Theories that stress the role of international trade in Asian growth predict rising capital shares and falling labor shares. Romalis (2004) finds that as the NIEs accumulated human and physical capital, their share of world production and exports of capital-intensive goods rose and their share of unskilled-labor-intensive production fell, implying capital's share of costs rose. Ventura (1997) extends a form of the factor price equalization theorem, and shows how small open economies can sustain rapid growth without diminishing factor returns. In essence, trade in goods is an

[23] Heterogeneity can also reflect differences in user-cost levels, but differing growth rates are a more direct source.
[24] Rhee (1997) discusses the dual structure of Korea's financial market.

indirect way to trade factors of production, which have diminishing returns only globally. Shifting production toward an export sector intense in a given factor need not imply a rapid decline in that factor's returns, so long as such exports replace use of that factor abroad.[25] Since the NIEs accumulated capital far faster than skill-adjusted labor, Ventura's explanation also implies rising capital shares and falling labor shares.[26]

We showed in line 1 of Table 2, however, that $(1 - s_L)$ fell over time in Singapore, Korea, and Taiwan – inconsistent with Ventura's predictions and surprising given Romalis's results. But note that our calculations in line 3 for "true" capital shares in cost, α, increased over time (line 4), albeit minimally in Korea. Hence, in addition to reconciling disparities between the dual and primal growth accounting results, our approach also resolves inconsistencies in Asia's growth experience with key results in the international trade literature.

6 Conclusion

Growth accounting is a useful and widely used tool for analyzing patterns of economic growth. For example, it provides insight into the role of factor accumulation versus technological progress in driving growth. However, results and interpretation can be sensitive to product and output market distortions. These distortions are often induced intentionally by policymakers, such as by providing favorable tax and other treatment to favored firms.

After discussing how these distortions might matter in principle, we show that they matter in practice for Singapore–the fastest growing economy in the world since 1960. Overall, technology growth during its fastest growth decades of the 1970s and 1980s was slightly negative. In the "favored" sector, where output grew nearly 10 percent per year for this period, technology growth was sharply negative. Our estimates resolve two important empirical puzzles regarding Asian development. First, we quantitatively reconcile divergent estimates of TFP growth from the dual and primal sides. Heterogeneity in the cost-of-capital (reflecting intentional programs to direct resources to particular firms and/or sectors) and large but declining pure economic profits explain much of the dual-primal gap. Second, we reconcile the constant or increasing labor shares in revenue with the intuitive story that rapid Asian growth relied heavily on a shift towards capital-intensive

[25] Under certain conditions, Ventura's application of factor-price equalization results implies truly constant factor prices. His explanation remains valid, however, as long as factor prices decline at slower rates than factors accumulated.

[26] Ventura's predictions for factor shares are relative to the rest of the world. In BLS or Jorgenson data for the United States, there is little evidence of a trend in factor shares over this period.

export sectors. The declining profit share allowed labor's share to remain flat or even rise despite a shift (which we document) towards capital-intensive sectors.

Our detailed examination of the NIEs provides both important caveats to, and new applications of, primal and dual growth accounting. When undertaking growth accounting for a country or across countries, there is value in carefully constructing both primal and dual measures. Resolving discrepancies can shed light on the underlying structure of the economy, in addition to providing insight into possible mismeasurement. Thus, this paper reinforces the message of a growing body of empirical and theoretical work that recommends looking inside the black box of aggregate growth accounting.

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Tables

Table 1: Asian Growth Estimates
(Percent per year)

	Output Growth per Capita (1960-1996)	Total Output Growth (1970-1990)	Total Factor Productivity	
			Primal Estimates	Dual Estimates
	(1)	(2)	(3)	(4)
Singapore	**8.2**	**7.8**	**-0.5**	**1.8**
Taiwan	8.0	8.8	2.2	3.7
Korea	7.5	9.5	1.7	1.9
Hong Kong	7.1	7.5	2.3	2.3
Unweighted Average	7.7	8.4	1.4	2.4

Notes: Column (1) is average annual log-change in "rgdpch" from Heston, Summers, and Aten (2002). Columns (2) and (3) are from Young (1998) for Singapore and Young (1995) for Taiwan, Hong Kong, and Korea. For Taiwan, data exclude agriculture and include Young's adjustment of public sector output. Column (4) is from Hsieh (2002). For each economy, Hsieh offers three or four different measures of TFP based on different measures of the real user cost; column (4) shows the average. Each measure is available for slightly different time periods; all measures approximately cover 1970 – 1990. In columns (2) and (3), we give the (weighted) averages across sub-periods of Young's primal TFP to match the time periods for Hsieh's dual TFP. Numbers may not add up due to rounding.

Table 2: Estimation of Capital and Profit Shares,1970-1990
(Except where indicated, all entries are percent per year)

		Singapore	Taiwan	Korea	Hong Kong
(1)	Share of capital and profits *(1-s_L)*	48.4	25.6	29.5	37.5
(2)	Growth in share of capital and profits	0.0	-0.2	-0.9	0.7
(3)	Estimated "true" capital cost share (using international data by industry)	32.6	30.1	24.8	32.6
(4)	Growth in "true" capital cost share	0.6	0.3	0.1	0.8
(5)	Estimated "true" capital revenue share	25.0	32.1	23.3	30.1
(6)	Growth in "true" capital revenue share	1.0	0.6	0.5	0.7
(7)	Estimated profit share	23.5	-6.5	6.2	7.4
(8)	Growth in profit share	-1.2	-3.3	-9.5	0.6

Notes: Line 1 shows the capital shares used by Young (1995, 1998) and also by Hsieh (2002). Line 3 is calculated as a weighted average of Sarel's (1997) capital share estimates, with the weights determined by the industry-share of GDP (1-digit SIC from the CEIC database). Line 7, the estimated profit share of revenues, is calculated as $(1 - s_L - \alpha) / (1 - \alpha)$, where α is the capital share of cost shown in line 3. (In line 8, since Taiwan's profit rate was negative and becoming more negative, we report the average change in the profit rate divided by the absolute value of the mean profit rate.) Finally, the capital share in revenues (line 5) is equal to Young's capital share (line 1) minus the estimated profit share (line 7). Numbers may not add up due to rounding

Table 3: Benchmark Calibration Results and Robustness Checks
(Except where indicated, all entries are percent per year)

	Technology Growth	Benchmark (1)	With ROE (2)	$K_F / K_U = 4$ (3)	α_i increased by 0.09 (4)	s_L increased by 0.08 (5)
(1)	Unfavored Sector	1.5	1.5	1.5	1.3	1.5
(2)	Favored Sector	-2.0	-1.9	-1.6	-1.4	-0.8
(3)	Aggregate Economy	-0.5	-0.5	-0.3	-0.3	0.1

Notes: Benchmark calculated using methodology described in Section 5. Aggregate technology calculated from sectoral technologies as $\widehat{a} = \omega_U \widehat{a}_U + \omega_F \widehat{a}_F$. Column (2) includes Hsieh's ROE-based measurement of the cost of capital in the average used to generate $\widehat{r}_U$. Column (3) increases the ratio of favored to unfavored capital from 2 to 4. Column (4) halves the aggregate profit share by arbitrarily increasing the capital share of costs (taken from international data) by 9 percentage points in every 1-digit sector. Column (5) halves the aggregate profit share by arbitrarily increasing the labor share of revenue estimate used in both the primal and dual by 8 percentage points. Numbers may not add up due to rounding.

Table 4: Decomposing the Sources of Difference in Primal and Dual Estimates
(Except where indicated, all entries are percent per year)

			Singapore	Taiwan	Korea	Hong Kong
(1a)	Wage growth	Young $\hat{w}$	1.8	4.0	4.2	3.6
(1b)		Hsieh $\hat{w}_{Dual}$	3.2	5.4	4.4	4.1
(2a)	Capital payment Growth	Young $\widehat{(r+\pi/k)}$	-2.9	-3.4	-4.3	0.1
(2b)		Hsieh $\hat{r}_{Dual}$	0.3	-1.2	-4.1	-0.5
(3)	Labor's share s_L (Sample average)		51.6	74.4	70.3	62.4
(4a)	Primal TFP growth		-0.5	2.2	1.7	2.3
(4b)	Dual TFP growth		1.8	3.7	1.9	2.3
(5)	Labor contribution to difference: $s_L(\hat{w}_{Dual}-\hat{w})$		0.7	1.0	0.1	0.3
(6)	Capital contribution to difference: $(1-s_L)\left(\hat{r}_{\text{Dual}}-\widehat{(r+\pi/k)}\right)$		1.6	0.6	0.1	-0.3
(7)	Difference (Dual-Primal)		2.3	1.6	0.1	0.1

Notes: Sample periods are adjusted to match Hsieh (2002). Lines (1b) and (2b) are the averages across the different measures reported by Hsieh (for which sample periods occasionally differ slightly). For Singapore, Young's primal data is taken from updated figures in Young (1998), other data are derived from Young (1995, Tables V, VII, and IX). Young's tables include data by subperiod for $\widehat{y}$, $\widehat{l}$, $\widehat{k}$, $\widehat{s}_L$ and $\widehat{s}_K$; we derive (implicit) growth in real factor prices from $\widehat{w}=\widehat{s}_L+\widehat{y}-\widehat{l}$ and $\widehat{r}=\widehat{s}_k+\widehat{y}-\widehat{k}$. We use a weighted average of growth rates over subperiods to adjust Young's numbers to cover the identical time period as each of Hsieh's measures (e.g., for a measurement of the 1973-1990 rate, we would take 7/17 of the 1970-1980 rate and add it to 10/17 of the 1980–1990 rate). The periods are all highly similar and approximately cover 1970 – 1990. When original growth rate calculations are needed (i.e. growth of average labor share), the best approximation to end points are used (i.e. for 1975-1990 growth rates, the calculation might use the 10-year growth from the average during the 1970-1980 period to that during 1980-1990). For Taiwan, data exclude agriculture and include Young's adjustment of public sector output. Numbers may not add up due to rounding.

Table 5: Contribution of Corporate Taxes to the User Cost

		Singapore	Taiwan	Korea	Hong Kong
		(1)	(2)	(3)	(4)
Aggregate Tax Adjustment	$\hat{t}$	-0.9	-0.6	-0.3	0.0
Contribution to dual-primal-gap	$-(1-s_L)\hat{t}$	0.4	0.2	0.1	0.0

Notes: The top line shows the estimated growth rate in the aggregate tax adjustment, $T = (1 - \tau D) / (1 - \tau)$. The second line shows the contribution to the dual-primal gap.

Table 6: Contributions to the Difference in Primal and Dual Estimates for Singapore (Except where indicated, all entries are percent per year)

		Using Average of Hsieh's Measures
(1)	Contribution of Profits to Difference (Dual-Primal)	0.8
(2)	(Residual) Contribution of Heterogeneous Costs of Capital to Difference (Dual-Primal)	0.3
(3)	Tax Correction Term	0.4
(4)	Capital Contribution to Total Difference (Dual-Primal)	1.6

Notes: Using the calculations in Tables 2 and 3, plus the disaggregation of the capital-payments contribution to the dual-primal gap in equation (14), and finally taking into account the gap attributable to the tax correction, we calculate lines 1 through 4 above. Numbers may not add up because of rounding.

Figures

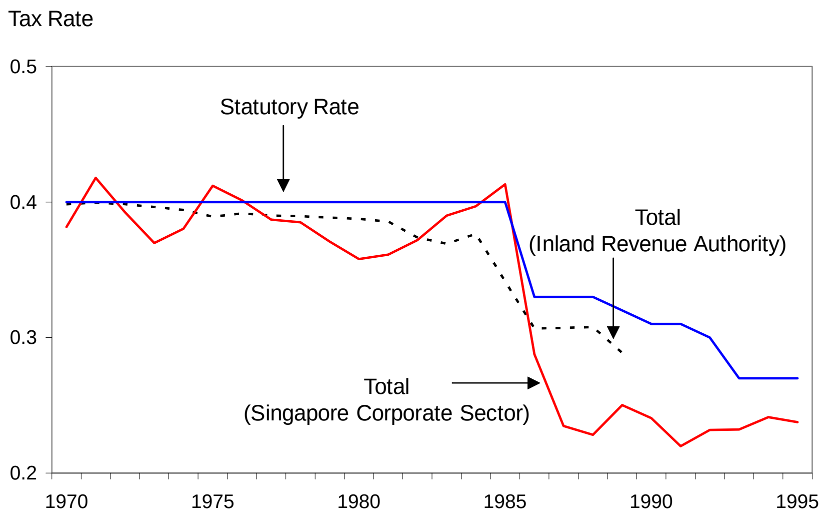

Figure 1A: Statutory Tax Rate and Average Rates Paid

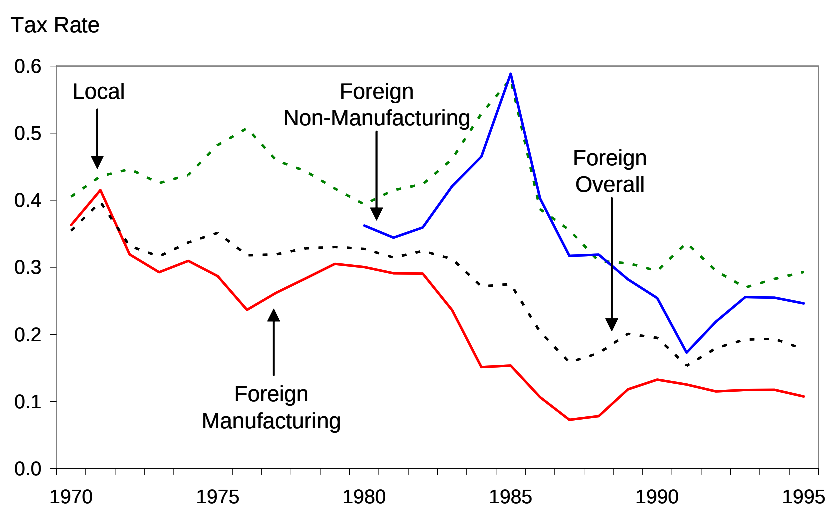

Figure 1B: Average Rates Paid for Different Firms

Notes: Sources are Inland Revenue Authority (various years) and Department of Statistics, Singapore (1992b, 1995, and 2006). Pre-1980 foreign manufacturing is estimated.

Appendix A: Aggregation, TFP, and Technology

This appendix gives details and derivation for the relationships given in section 3.3 on sectoral and aggregate TFP and technology in a two-sector economy. Using the Divisia index for aggregate output, from the text, we can write aggregate TFP growth as:

$$
\begin{aligned}
\widehat{y} - s_L \widehat{l} - (1 - s_L)\,\widehat{k} &= \sum_{i=F,U} \omega_i \left(\widehat{a}_i + \alpha_i \widehat{k}_i + (1 - \alpha_i)\,\widehat{l}_i\right) - s_L \widehat{l} - (1 - s_L)\,\widehat{k} \qquad \text{(B1)} \\
&= \widehat{a} + \left(\sum_{i=F,U} \omega_i \alpha_i \widehat{k}_i - (1 - s_L)\,\widehat{k}\right) + \left(\sum_{i=F,U} \omega_i (1 - \alpha_i)\,\widehat{l}_i - s_L \widehat{l}\right).
\end{aligned}
$$

The last term in parenthesis in equation (B1) is a weighted average of the contribution of labor to output in the two sectors, minus aggregate labor growth multiplied by labor's aggregate share. We can write this term out and rearrange as:

$$
\sum_{i=F,U} \omega_i (1 - \alpha_i)\,\widehat{l}_i - s_L \widehat{l} = \sum_{i=F,U} \frac{wL_i}{PY} \left(\frac{P_i Y_i}{R_i K_i + wL_i} - 1\right) \widehat{l}_i. \qquad \text{(B2)}
$$

The term on the right-hand-size of (B2) corresponding to $i = U$ is zero because, with no pure profits in the unfavored sector, $P_U Y_U = R_U K_U + wL_U$. For the $i = F$ term, note that $P_F Y_F / (R_F K_F + wL_F) = 1 + \Pi_F / (R_F K_F + wL_F)$, so the overall expression simplifies considerably:

$$
\sum_{i=F,U} \omega_i (1 - \alpha_i)\,\widehat{l}_i - s_L \widehat{l} = (1 - \alpha_F)\, s_\Pi \widehat{l}_F. \qquad \text{(B3)}
$$

Note that we have used the assumption that all profits are in the favored sector, so $\Pi = \Pi_F$. In essence, the only reason the aggregate estimate $s_L \widehat{l}$ differs from the share-weighted output contribution of the individual sectors is because of profits, which occur only in the favored sector.

Now consider the first, capital-growth-related, term in parenthesis in equation (B1). Noting that $1 - s_L = s_K + s_\Pi$ and $R = \sum (K_i/K)\, R_i$ (which implies $R_i - R = (K_{-i}/K)(R_i - R_{-i})$ for $i = F, U$), we can express this term as:

$$
\begin{aligned}
\sum_{i=F,U} \omega_i \alpha_i \widehat{k}_i - (1 - s_L)\,\widehat{k} &= \sum_{i=F,U} \left(\frac{R_i K_i}{PY}\right) \left(\frac{P_i Y_i}{R_i K_i + wL_i} - \frac{R}{R_i}\right) \widehat{k}_i - s_\Pi \widehat{k} \qquad \text{(B4)} \\
&= \left(\frac{\Pi_F}{PY}\right) \left(\frac{R_F K_F}{R_F K_F + wL_F}\right) \widehat{k}_F + \sum_{i=F,U} \left(\frac{K_i (R_i - R)}{PY}\right) \widehat{k}_i - s_\Pi \widehat{k} \\
&= \left(\frac{\Pi_F}{PY}\right) \left(\frac{R_F K_F}{R_F K_F + wL_F}\right) \widehat{k}_F + \sum_{i=F,U} \frac{K_i K_{-i}}{PY} \frac{(R_i - R_{-i})}{K} \widehat{k}_i - s_\Pi \widehat{k} \\
&= s_\Pi \left(\alpha_F \widehat{k}_F - \widehat{k}\right) + \frac{K_F K_U}{KPY} (R_F - R_U) \left(\widehat{k}_F - \widehat{k}_U\right)
\end{aligned}
$$

Combining (B1), (B3), and (B4), we have equation (11) in section 3.3: $\widehat{tfp} = \widehat{a} + s_\Pi \left(\widehat{x}_F - \widehat{k}_F\right) + \Sigma_K$. Thus, revenue-share-weighted TFP growth differs from technology growth because of two terms – one which reflects profits and one which reflects reallocations of capital across uses.

Using a cost-share-weighted aggregate residual would change the form of these terms, but would not eliminate them. In particular, following a similar analysis, one finds:

$$\widehat{y} - (1-\alpha)\,\widehat{l} - \alpha\widehat{k} = \widehat{a} + (1 - s_{\Pi})^{-1}\,(\Sigma_{\Pi} + \Sigma_{K})$$

where $\Sigma_{\Pi} = \omega_U s_{\Pi}\,(\widehat{x}_F - \widehat{x}_U)$ and Σ_K reflect reallocations of inputs across uses. The first term represents shifts of resources toward the favored sector (where the profit rate is higher and hence its share in output exceeds its share in cost). Economically, this reflects that output is measured using relative market prices, not relative costs of production. With differential profit rates, relative prices need not equal relative costs of production (i.e. the marginal rate of substitution is not equal to the marginal rate of transformation). Output is (quite appropriately) aggregated using prices, which are equated to marginal rates of substitution, not using marginal rates of transformation. The second reallocation term reflects the fact that if capital is shifted to where it has a higher cost, aggregate output and TFP rises, other things equal. With a higher cost of capital, firms' cost-minimizing conditions for capital input use imply that the marginal product of capital is higher. Reallocating resources to where their marginal products are higher raises aggregate output.

Appendix B: Data Sources and Discussion

This appendix gives details corroborating measurements that use from previous authors and national accounts, as well as giving the details behind our construction of novel data series used in our analysis.

Confirming Singapore's Labor Share

To verify the labor share figures used by Young (1994) and Hsieh (2002), we used the GDP by income components data from Singapore Statistics. These data were produced for the first time in the late 1990s, so they were not available when Young did his work; they are available only back to 1980. Since we want factor shares in output measured at prices received by producers (i.e., prices that include indirect taxes on factors of production, such as property taxes, license fees, motor vehicle registration fees, and so forth), we also used Singapore Statistics data on gross value added at basic prices (part of their GDP by industry data). Finally, we obtained data on self-employment from various Censuses of Population and from Singapore Statistics (1993).

Labor's share is often low in developing countries because self-employment income (e.g., from farming) is allocated to capital not labor. Gollin (2002) reports that after correctly allocating proprietors' income (i.e. self-employment income), labor shares are almost always in the range of 0.65 to 0.8.

Unallocated proprietors' income does not explain Singapore. In data on income components of GDP, proprietors' income was only 10 percent of gross value added at basic prices in 1980 and 7 percent by 1990. Labor's share, which incorporates all compensation including employers' contributions to the CPF and private pension/insurance funds, was 40 percent in 1980 and 45 percent in 1990, so any reasonable allocation of proprietors' income will keep labor's share at around 50 percent. This data source does suggest that labor's share might have edged up a bit over time.

To measure factor shares, Young's figures use the input-output tables, which properly incorporate all capital-related taxes in capital income (i.e., they correspond to gross value added at basic prices). In 1990, the input-output tables have a labor share of 44 percent. (They thus differ only very slightly from the more recently produced GDP-by-income-components data, which incorporate more recent revisions including minor methodological changes.) He then imputes wages for proprietors and unpaid family workers using micro data. Gollin cites Young (1995) as exemplifying the "best approach" to estimating factor shares (Gollin, p. 467). Despite differences in data sources, his figures are fairly consistent with the income-components data.

A few studies have proposed replacing Singapore's actual labor share of 1/2 with a more "normal" labor share of 2/3. (For example, IMF, 2004) One justification, as in Sarel (1997), is that such shares might better measure true shares in cost. In our two-sector model of Section 3, however, it is not appropriate to simply use cost shares – one needs to estimate from the bottom up.

In our view, one needs to understand why labor's share is so low: One cannot arbitrarily adjust it because it is out of line with other economies. In any case, adjusting capital's share down doesn't reconcile Young with Hsieh. Young's figures still imply that capital returns fell at nearly 3 percent per year, whereas Hsieh's suggest that the user cost was about constant.

TFP Estimates

Dual data calculations are from Hsieh (2002); his detailed spreadsheet was obtained from http://www.wws.princeton
on June 13, 2003. Primal estimates are from Young (1995, 1998). Series on multifactor productivity

were purchased from Singapore Statistics on February 23, 2006. These figures are available from 1973 on; the major conceptual difference from Young is that they do not adjust labor or capital for quality or composition. Average unadjusted TFP growth was only 0.7 percent per year from 1973-90 – indeed, TFP growth was negative from 1973-1985. These figures are very close to Young's unadjusted TFP growth from 1970-90. Young's input-composition adjustment removes about 1.2 percent per year from the unadjusted figures.

National Accounts

GDP by expenditure data were downloaded from Singapore Statistics, via CEIC Asia. These include investment data, which we used to construct capital stocks. In particular, gross fixed capital formation data by sector (public and private) and by type of capital (residential buildings, nonresidential buildings, other construction and works, transport equipment, and machinery and equipment) from 1960 to 2005 were downloaded from CEIC Asia Database on March 17, 2006. Real investment is measured in S$2000 prices.

These investment data were used to construct perpetual inventory measures of each type of capital stock. Depreciation rates follow Hsieh: residential = 0. 0.013, nonresidential buildings = 0.029, other construction = 0.021, transport = 0.182, and machinery and equipment = 0.138. Initial 1960 values of the capital stock were set at the 1960 value of investment, divided by the sum of the average

investment growth from 1960 to 1965 and the depreciation rate for each type of capital.

Capital input aggregates are measured as share-weighted growth rates (i.e., as Tornquist indices). The weights are estimated user costs of each type of capital, measured as a constant real interest rate equal to 0.05 plus the depreciation rate, multiplied by the nominal value of each type of capital. Capital input is not very sensitive to the assumed real interest rate.

One-digit GDP-by-industry data are also from CEIC and were downloaded in February 1999. For Hong Kong, industry data for 1970-79 are from United Nations (1979, 1984). For Singapore, we also downloaded updated data on February 2, 2006. The updated data include owner-occupied dwellings as a separate industry; rental housing, however, remains a part of the much broader "finance, insurance, and real estate. GDP by income component were purchased from Singapore Statistics (http://shop.asiaone.com/stores/singstat/gdi.html) on February 1, 2006. Dale Jorgenson's industry dataset for the United States was downloaded from http://post.economics.harvard.edu/faculty/jorgenson/data/35klem.html in October 2002.

Pre-Tax Profit or Loss, and Taxation by Industry

Provisions for taxes by local-controlled and foreign-controlled firms as well as by sector are from Department of Statistics, Singapore (1992b, 1995, 2006). These rely on corporate financial reports, and also report net income by sector as well as selected balance sheet information.

Hsieh (2002) used assessed corporate taxes from various annual reports of the Inland Revenue Authority (we thank him for making his data available). These report assessed taxes rather than taxes paid (as Asher, 1989, discusses). The Inland Revenue and corporate-sector data track reasonably well, but note that we do not expect them to track perfectly. For example, total corporate-reported net earnings include firms that make losses, and hence owe no tax; this raises the average rate paid. In contrast, the Inland Revenue measure of assessed income is for firms owing tax, not for all firms, so it excludes this source of volatility. In addition, corporate net income uses accounting measures of depreciation whereas assessed income uses tax depreciation.

Data on U.S. Multinationals are from the Bureau of Economic Analysis (BEA) annual survey of U.S. direct investment abroad. Files from 1983 onward were downloaded in March 2006 from http://www.bea.gov/bea/ai/iidguide.htm#link12b. Earlier data was obtained from the BEA in hardcopy. Desai, Foley, and Hines (2002) have an extensive discussion of these data. We thank Ariel Burstein for providing the cross-country average-tax-rate data in summary form.

Return on Equity and Net Fixed Assets

Asset data taken from the Department of Statistics, Singapore (1992a). This is the report cited by Hsieh as the source of ROE data; but ROA data (not ROE data) are found in the report. Numbers consistent with Hsieh's ROE calculations are found in Department of Statistics, Singapore (1995). Department of Statistics, Singapore (1992b, 1995, 2006) also includes book-value estimates of net fixed assets (NFA) in the corporate sector.

Present Value of Depreciation Allowances

To calculate the present value of depreciation allowances in Singapore, we consider the four major types of non-residential capital identified in the national accounts: Machinery, transport equipment, industrial buildings, and other construction. (We exclude residences, even for private investment, on the grounds that a large share of it is presumably owner-occupied rather than business-owned.) We use information on the tax code from Commerce Clearing House (various years) and Inland Revenue Authority (various years). These sources identify the initial and annual allowances, as well as the type of accounting required – declining balance or straight-line. The major changes over the 1970-90 period are (i) in 1978, initial and annual allowances for industrial buildings become much more generous; and (ii) in 1980, allowances for transport and machinery become more generous because of the move from declining-balance to straight-line depreciation.

We assume that other construction received the same treatment as industrial buildings. We also assume firms did not take advantage of accelerated depreciation for equipment, since until the late 1980s it was available only to manufacturing firms, most of whom were foreign and many of whom had pioneer status. A firm with pioneer status (and thus a low or even zero tax rate) would generally prefer to preserve some of the depreciation for the post-pioneer period, when income became taxable. In the mid-1980s, accelerated depreciation for equipment became available to all firms, which would accentuate the rise in the present value of depreciation allowances relative to our conservative calculation, and hence would accentuate the decline in the user cost of capital.

We use a constant nominal interest rate of 8 percent to calculate the present value of allowances D_i for each type of capital. We confirmed that results are not sensitive to using other rates (e.g., 6 percent or 10 percent), or to using the actual time series on interest rates used by Hsieh (2002).

To obtain an overall weighted average D, we weight the separate D_i by estimated shares in capital income, calculated assuming a real rate of 5 percent. Results are not particularly sensitive to the specific weights, since allowances for all types of capital became more generous.

Estimating Tax Rate for Foreign Multinationals Pre-1980

Department of Statistics, Singapore (1992b) provides summary profit/loss statements for Singapore's corporate sector beginning in 1980. These data have net income before tax (or profit/loss) as well as provisions for income tax, from corporate financial statements. These data are available for the entire corporate sector, as well by major industry, and for local-controlled versus foreign-controlled firms. These data begin in 1980. For the 1970-1979 period, Singapore Statistics provided us with selected data for local- and foreign-controlled firms; industry income-statement data are not, however, available, though selected balance sheet data are. Conceptually, the overall tax rate for foreign-controlled firms is the share-weighted average of foreign manufacturing and foreign non-manufacturing. We assume manufacturing's share of net profits are proportional to their share of net fixed assets, and assume that non-manufacturing firms pay the same average rate as local firms. These two assumptions allow us to estimate the rate for foreign manufacturing. For the period from 1980 on, the estimated rate is quite similar to the actual rate. We splice the estimated and actual data in 1980. Results in the text appear robust to reasonable alternative choices, such as using the statutory rate for non-manufacturing firms, or using the manufacturing share from 1980.

Tax Parameters for Hong Kong, Korea, and Taiwan

The main source of depreciation allowances and investment tax credits is Price Waterhouse, "Corporate taxes, a worldwide summary." For Taiwan, other sources included Price Waterhouse, "Doing Business in Taiwan," 1989, 1991 and 1996, and Deloitte, Haskings, & Sells "Taxation in Taiwan, ROC (Republic of China)" (1982). Tax rates were obtained by email from Taiwan's Ministry of Finance (April 2006) and from Chou and Wu (1994). For Korea, corporate tax rates are from Hyun et al (2000). Other sources were Price Waterhouse's "Doing Business in Korea" (1992). For Hong Kong, our sources were Ho (1979) and Ho and Chau (1988). We confirmed the depreciation schedules with Hong Kong's Inland Revenue Department. Further details on our calculations are available from the authors.

Surpluses of Statutory Boards

Current surpluses of seven major statutory boards are from the Economic Survey of Singapore (various issues). The seven are the Housing and Development Board (HDB), Jurong Town Corp (JTC), Public Utilities Board (PUB), Port of Singapore Authority (PSA), Telecommunications Authority of Singapore (Telecoms), Urban Redevelopment Authority (URA), and Sentosa Development Corp (SDC). Singapore Statistics confirmed in personal correspondence on March 20, 2006 that current surpluses of SBs that produce market output are included in corporate gross operating surplus.

Appendix C: Systematic National Accounting Errors?

This appendix discusses the hypothesis, plausible in principle, that systematic errors in the national accounts could reconcile the primal and the dual. In particular, Hsieh (2002) suggests that the national accounts overstate growth in the capital-output ratio by about 3 percentage points per year. Hsieh's example of national accounting errors concerns output rather than investment: Singapore uses a low, subsidized rental rate to measure the service flow from owner-occupied housing.[27] This suggests that the accounts might understate nominal housing, though not necessarily its real service flow, which rose 11 percent per year from 1970-1990. Suppose mismeasured housing services caused us to understate true output growth by 3 percent per year from the mid-1960s to 1990. Then by 1990, true output would have been more than twice its measured level (i.e., 3 percent compounded for 25 years) – making Singapore by far the richest country in the world, with owner-occupied housing accounting for over half of GDP. Singapore was quite wealthy by 1990, but these counterfactuals seem implausible.[28]

Could Singapore instead have overstated capital growth by 3 percentage points per year? Suppose there were growing errors in real investment from the mid-1960s on. Like most countries, Singapore measures expenditure from ongoing surveys of its components. Large errors in the investment surveys would not be offset by large errors in the consumption surveys. Hence, both output and the GDP deflator would also be mismeasured (and incorrect when used for the dual). But Singapore uses different surveys to measure GDP from the expenditure, output, and income sides. If expenditure-based nominal GDP were mismeasured, then there would counterfactually be a large and growing statistical discrepancy.

Might the investment deflator grow too slowly? After adjusting the machinery and equipment deflator for exchange-rate changes, the growth in Singapore's deflator rises about 2 percentage points per year faster than the U.S. deflator from 1970-1990 – consistent with Singapore not incorporating hedonic adjustments into their deflators.[29] Hence, Singapore plausibly understates rather than overstates real investment growth.

A more plausible way to reduce capital growth is to raise the initial level of investment. In the 1960s, gross fixed capital formation averaged 18 percent of GDP; this share rose to 36 percent in the 1970s and to 40 percent in the 1980s. Suppose we raised the share of investment in GDP to 36 percent for each year from 1960-1969 and then reestimate capital growth. From 1970-90, this alternative capital series grows 3.2 percent per year less than what the national accounts suggest. (The 1960 level of capital is benchmarked as $I_{60}/(g+\delta)$, where g is the average growth from 1960 to 1965; this alternative path raises the estimated initial capital level about nine-fold.)

Nevertheless, such an increase in initial investment and capital seems unlikely. First, it implies, counterfactually, a statistical discrepancy averaging 18 percent of GDP in the 1960s; the actual discrepancy was fairly small (see Young, 1998). Second, the 1960s were a time of political upheaval and civil unrest, so the investment climate was not particularly favorable relative to the '70s and '80s. Third, Young (1995) uses data on residential construction and retained imports of cement to extend structures investment back to 1947; those figures do not suggest widespread errors in the initial capital or investment values in the 1960s. Finally, Hsieh provides no evidence of major

[27] If marginal rates of substitution reflect the subsidized rate then Singapore's treatment is appropriate. But if subsidized housing is quantity-rationed, then this rate is not the right shadow value.

[28] Non-housing TFP growth is virtually identical to overall TFP growth. Non-housing output rises 0.1 pp per year more slowly from 1970-1990 than overall output; non-housing capital grows 0.1 pp per year faster. In addition, labor's share of income increases by 0.02 (since housing services are part of capital income), so on balance, share weighted inputs rise about 0.1 pp per year more slowly.

[29] In personal correspondence (March 23, 2006), Singapore Statistics confirmed that they have not implemented any hedonic adjustments to their investment deflators.

underestimates of initial investment and capital.

In sum, Hsieh has identified an interesting puzzle. But before relying on the unsupported hypothesis of large scale national accounting errors, one needs to assess other probable explanations.