Special Feature

Sources of Singapore's Economic Growth 1990-2009[1]

Introduction

As the world economy emerges from the global financial crisis, countries need to look beyond short-term cyclical factors and focus on supply-side drivers that will ensure sustainable growth over the longer term. Accordingly, the identification and analysis of the historical sources of economic growth can provide useful insights into the future evolution of an economy.

This Special Feature presents a supply-side analysis of Singapore's economic growth over the period 1990-2009. Using a growth accounting approach, we decompose the aggregate growth rate of the economy into capital input, labour input, as well as technological progress and intangible socio-economic improvements, collectively known as total factor productivity (TFP).

The growth decomposition framework is based on Jorgenson *et al*. (2003), which introduced an important innovation by explicitly estimating the impact of information and communication technology (ICT) investment on economic growth and productivity.[2] This augmentation to the traditional growth accounting framework is particularly important for Singapore, given the significant and widespread reliance on ICT in many sectors of the economy, including education, business services and communications.

Best practice in the growth accounting literature also suggests that changes in labour quality ought to be taken into account when explaining the sources of economic growth. This is particularly pertinent for Singapore given the constraints on labour force growth. Accordingly, we estimate the quality of human capital over the period 1990-2008 together with its contribution to labour input, and hence, to economic growth.

In the following sections, the growth decomposition framework is briefly explained, followed by a description of the estimated ICT investment series and the derived labour quality series. Key results for Singapore are then highlighted, followed by an assessment of the prospects for labour productivity growth in the period 2010-19. Finally, some policy implications are considered.

1 This Special Feature was written in collaboration with Assistant Professor Vu Minh Khuong from the Lee Kuan Yew School of Public Policy, National University of Singapore.

2 This approach has been widely adopted in studies of the US and other OECD economies. See, for example, Van Ark and Timmer (2005) and Van Ark *et al*. (2008).

A Growth Decomposition Framework

The empirical work in this Special Feature adopts the growth decomposition framework set out in Jorgenson *et al*. (2003), which uses an extended production possibility frontier (PPF) model to capture the impact of ICT on economic growth.

The PPF describes the efficient combinations of inputs and outputs for the economy as a whole. Aggregate output Y consists of investment goods and consumption goods, produced from aggregate input X, which in turn, comprises capital services and labour input.

More importantly, capital services are classified into ICT capital K_{ict} and non-ICT capital K_{nict}, while the services provided by labour input are computed as the product of total hours worked H and the labour quality index L_Q.[3] Equation (1) shows the PPF relation more formally, with A representing "Hicks-neutral" technological change.

$$Y = A.X(K_{ict}, K_{nict}, H, L_Q) \qquad (1)$$

Under neoclassical assumptions of competitive markets and constant returns to scale, equation (1) can be further transformed into a growth accounting decomposition:

$$\begin{aligned}\Delta\ln Y = {} & \bar{v}_{K_{ict}}\Delta\ln K_{ict} + \bar{v}_{K_{nict}}\Delta\ln K_{nict} \\ & + \bar{v}_L\Delta\ln H + \bar{v}_L\Delta\ln L_Q + \Delta\ln A\end{aligned} \qquad (2)$$

where $\bar{v}$ represents the average share in total factor income of the subscripted input and A denotes total factor productivity (TFP). All variables are expressed in logarithmic first differences to represent their growth rates.

This decomposition thus permits the sources of GDP growth to be allocated to the contribution of capital input ($\bar{v}_{K_{ict}}\Delta\ln K_{ict} + \bar{v}_{K_{nict}}\Delta\ln K_{nict}$); labour input ($\bar{v}_L\Delta\ln H + \bar{v}_L\Delta\ln L_Q$); and TFP ($\Delta\ln A$).

The contribution of capital input can then be further divided into the contribution of ICT ($\bar{v}_{K_{ict}}\Delta\ln K_{ict}$) and non-ICT capital services ($\bar{v}_{K_{nict}}\Delta\ln K_{nict}$); and the contribution of labour input can similarly be sub-divided into hours worked ($\bar{v}_L\Delta\ln H$) and labour quality ($\bar{v}_L\Delta\ln L_Q$).

Equation (2) can also be re-written in terms of average labour productivity (ALP) growth:

$$\begin{aligned}\Delta\ln y = {} & \bar{v}_{K_{ict}}\Delta\ln k_{ict} + \bar{v}_{K_{nict}}\Delta\ln k_{nict} \\ & + \bar{v}_L\Delta\ln L_Q + \Delta\ln A\end{aligned} \qquad (3)$$

where y denotes ALP or the ratio of output Y to hours worked H, and k is defined as the ratio of capital services K to hours worked H.

As shown in equation (3), ALP growth is driven by three factors: ICT and non-ICT capital deepening ($\bar{v}_{K_{ict}}\Delta\ln k_{ict} + \bar{v}_{K_{nict}}\Delta\ln k_{nict}$) or the effects of capital-labour substitution; improvements in labour quality ($\bar{v}_L\Delta\ln L_Q$) and TFP growth ($\Delta\ln A$).

The hallmarks of this particular framework are heterogeneous capital services, with emphasis on the services provided by ICT equipment and software; and labour quality, to capture the impact of changes in the composition of the labour force, such as education attainment and wage structure, on output growth. These two concepts are discussed in greater detail in the next two sections.

[3] The assumption made in this study is that the average hours worked per employee remained unchanged over the period 1990-2008. Employment figures can, therefore, be used instead of hours worked for the empirical estimate. In the paper, the terms “total hours worked” and “total employment” are interchangeable.

ICT Investment in Singapore

Since the 1990s, the widespread diffusion and application of ICT around the world has generated an increasing spectrum of ICT-based economic activities. Understanding the impact that these activities have on the economy is important, given the strong orientation that Singapore has towards ICT-related industries and its pervasive adoption of ICT in both manufacturing and services.

ICT investment essentially consists of three types of capital goods formation, namely, computer hardware, computer software and telecommunication equipment. Two distinctive features are usually associated with ICT investment: the rapid decline in the prices of these assets and their relatively high rate of depreciation. These characteristics imply that the user cost of ICT capital services will generally be higher than typical non-ICT capital services, and they, therefore, require a higher rate of return. Consequently, ICT investment provides a higher contribution to GDP growth than non-ICT investment.

There are three main channels through which investment in ICT directly impacts economic growth. First, it adds to the capital stock that is available for workers and thus raises labour productivity. Second, the ICT-producing sector itself is a source of growth, largely due to rapid growth in the market for ICT products and technological advance inherent in this sector that continuously raises its productivity. Third, the use of ICT enhances TFP by increasing firms' efficiency in combining labour and capital inputs.

Estimating ICT Investment

A method pioneered by Van Ark and Timmer (2005) is used to estimate current-price ICT investment flows in an ICT asset type.[4] This involves two steps. First, using the *Singapore Input-Output Tables 2000*, current price investment flows, defined as gross fixed capital formation, are derived for each of the three ICT asset types for the year 2000. Second, projections are made for the annual ICT investment series for each ICT capital asset based on investment in 2000 and the assumption that the nominal growth of investment in each ICT asset type is proportional to its nominal sales growth in the domestic market.[5] In turn, the latter is a weighted average of two sources: the sum of domestic production less exports and retained imports; and local revenues reported by the ICT sectors.

Accordingly, the following equation is used to estimate investment $I_{i,t}$ for ICT asset i in year t:

$$I_{i,t} = \lambda \cdot \left(\frac{Q_{i,t} + M_{i,t} - X_{i,t}}{(Q_{i,2000} + M_{i,2000} - X_{i,2000})} \right)^{0.5} \cdot I_{i,2000} + (1-\lambda) \cdot \left(\frac{R_{i,t}}{R_{i,2000}} \right)^{0.5} \cdot I_{i,2000} \qquad (4)$$

where $Q_{i,t}$ is domestic production; $M_{i,t}$ is retained imports; $X_{i,t}$ is domestic exports and $R_{i,t}$ is the local revenues generated by the ICT sector.[6] λ and (1-λ) are the weights applied to the two estimates of domestic sales.[7]

4 This is an improvement over the methodology adopted in most studies, including Khatri and Lee (2003), which estimate ICT investment flows using data on ICT expenditure provided by the *WITSA/IDA Digital Planet* publication.

5 The correlation between investment growth and sales growth is somewhere between 0 (investment is unchanged while sales grow) and 1 (investment and sales grow at the same rate). It is reasonable to choose the mid-point, 0.5, to estimate the investment growth rate, hence the exponential of 0.5 in equation (4).

6 Data on domestic ICT production, exports and revenue are obtained from EDB's *Census of Industrial Production*, IE Singapore, and IDA, respectively.

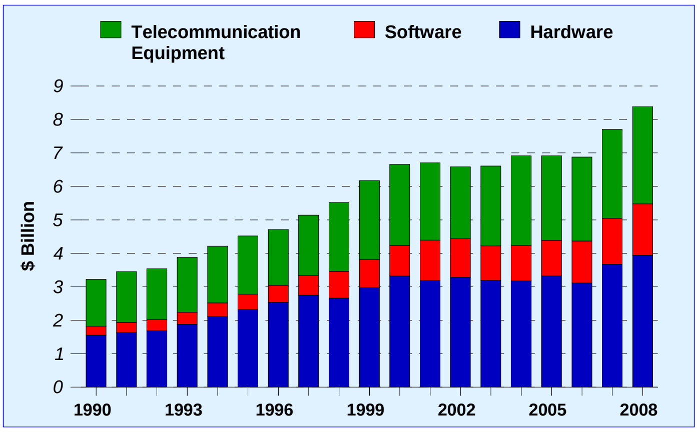
7 For hardware and telecommunication equipment, a smaller weight is assigned to the first component (with λ calibrated at 0.3), as it is a less robust proxy for investment growth relative to the second component, given that the source of the production data is different from that of the trade statistics. For software, the estimation relies only on the second component, i.e. λ = 0, as there are no comparable data for the first component given that Singapore is not a large producer and exporter of software.

Results

Over the period 1990-2008, ICT investment in Singapore increased, on average, by about 5.5% per annum. It also rose sharply between 1997 and 2000 amidst the global ICT investment boom and sharp decline in the prices of ICT products after 1995.[8] Growth became more subdued in the aftermath of the 2001 dotcom crash before reviving more recently in 2007-08. Chart 1, which presents a breakdown by type of ICT investment, further shows that about half of ICT expenditure consistently went into the acquisition of computer hardware and that investment in software only became important after about 1998.

Over the same period, ICT investment accounted for an average of 13% of overall GFCF in Singapore and, as a share of GDP, remained fairly stable at around 4%. (Chart 2a) In comparison, non-ICT investment as a share of GDP fell from 31% in the 1990s to 22% in 2000-08.[9] A cross-country comparison suggests that Singapore's share of ICT investment in GDP in 2005 was higher than in many other countries, coming fifth after Denmark, Sweden, Australia and the US. (Chart 2b)

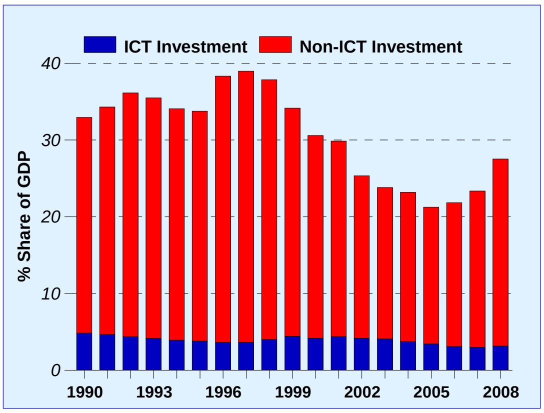
Chart 1
Types of ICT Investment in Singapore



Source: EPG, MAS estimates

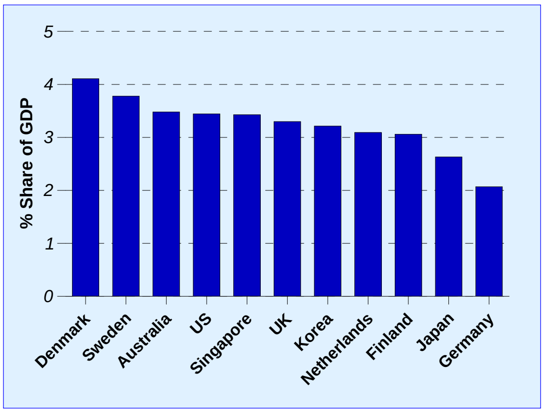
Chart 2

(a) ICT and Non-ICT Investment in Singapore



Source EPG, MAS estimates

(b) ICT Investment Across Countries, 2005



Source: EU KLEMS Database and EPG, MAS estimates

8 Jorgenson *et al*. (2008) observed that the growth rate of ICT investment in the US increased from 14% in 1987-95 to 22% in 1995-2000, while the decline in information technology prices accelerated from -3.3% to -7.3% per year.

9 The steady decline from the late 1990s to 2005 was largely due to the fall-off in private construction investment.

A Labour Quality Index for Singapore

Estimating Labour Quality

The composition of the workforce is dynamic and may be affected, for example, by changes in education attainment and the number of years of working experience. These changes, moreover, affect the stock of human capital and the associated returns to economic growth over time. Standard unadjusted measures of labour input, which do not generally account for such changes in human capital or labour quality, thus tend to underestimate the contribution of labour input to economic growth.

The methodology in Jorgenson *et al*. (2005) is used to construct a labour quality series for Singapore over the period 1990-2008 to overcome the limitations associated with standard unadjusted labour input measures. Education attainment based on six levels of education – Primary & Below, Lower Secondary, Secondary, Post Secondary, Diploma, and Degree – is used as a proxy for the human capital obtained through formal schooling.[10]

The estimates of labour quality are constructed in two stages. First, data on education and the gender profile of the workforce is used to derive weights for each of 12 worker groups.[11] These weights reflect differences in productivity (as proxied by wages) across the worker groups. For example, workers with tertiary education tend to, on average, be more productive, and hence command higher wages, as compared to workers with only primary education and are, therefore, assigned larger weights.

The weighting or value share assigned to each labour group is based on the following equation:

$$\bar{v}_{l,t} = \frac{1}{2}\left[\frac{W_{l,t}H_{l,t}}{\sum_{l} W_{l,t}H_{l,t}} + \frac{W_{l,t-1}H_{l,t-1}}{\sum_{l} W_{l,t-1}H_{l,t-1}}\right] \quad (5)$$

where $\bar{v}_{l,t}$ is the two-period average share in the value of labour compensation of worker group l in time *t;* and $W_{l,t}$ and $W_{l,t-1}$ is the average wage of worker group l in year *t* and *t-1*, respectively.

These weights are then used to adjust the data on total hours worked by each worker group to arrive at an index of labour quality adjusted labour input which is equivalent to:

$$L_t = \prod_{l} (H_{l,t})^{\bar{v}_{l,t}} \quad (6)$$

where L_t is expressed as a Tornqvist index over the 12 types of workers, and $H_{l,t}$ is the total hours worked in year *t* by worker group l.

Finally, the labour quality index (also called the labour composition index) is then obtained from the ratio of quality-adjusted labour services to total hours worked, as shown in:

$$L_{Q_t} = \left(\frac{L_t}{H_t}\right) \quad (7)$$

10 It should be noted that the level of education is a limited proxy for human capital. In addition to formal education, workers also gain human capital through increased labour market experience and on-the-job training, which could be proxied by age. See for example Thangavelu and Yong (2006).

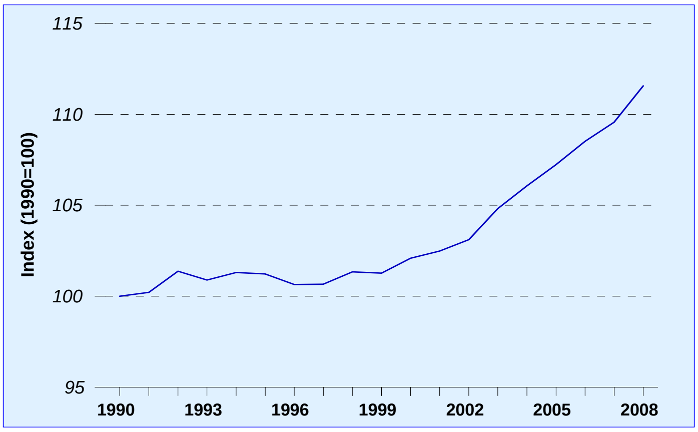
11 Employment data is estimated by EPG, MAS. Shares of employed persons in the twelve worker groups are calculated using the survey-based data from the Labour Force Survey (LFS) and applied to administrative employment records from the Central Provident Fund. Median wage data is obtained directly from the LFS. For population census years (1990, 1995, 2000 and 2005) when the LFS is not conducted, a simple interpolation method is applied.

Results

Chart 3 shows that labour quality has been on an upward trend since 1990, growing by an average of 0.6% p.a. until 2008. This reflects the decline in the share of the workforce with little or no formal schooling (primary & below) and a corresponding rise in the share of those with tertiary education (diploma and degree). (Chart 4a) More recently, there has been a significant increase in the quality of human capital due, in part, to an influx of skilled foreign workers.

These substantial improvements in labour quality are consistent with ongoing government policies to develop the human capital base, given the lack of natural resources in Singapore. Indeed, by 2007, the share of economically active residents aged 25-64 with tertiary education exceeded the OECD average although several countries still significantly out-rank Singapore. (Chart 4b)

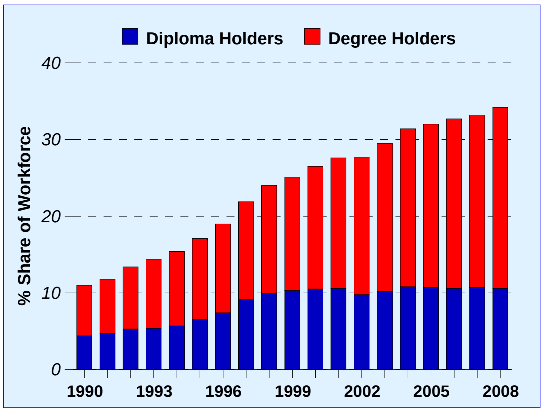
Chart 3
Labour Quality Index



Source: EPG, MAS estimates

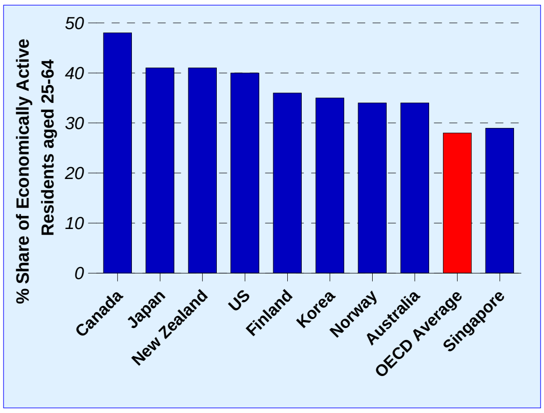
Chart 4

(a) Share of Workforce with Tertiary Education in Singapore



Source: MOM and EPG, MAS estimates

(b) Share of Economically Active Residents with Tertiary Education, 2007



Source: OECD and EPG, MAS estimates

Sources of Singapore's GDP and Average Productivity Growth, 1990-2009

The sources of Singapore's GDP growth and labour productivity growth over the period 1990-2009 are estimated on the basis of equations (2) and (3), respectively. For the purpose of this analysis, the data is divided into the two decades, corresponding to the periods 1990-99 and 2000-09. Detailed results are presented in Tables 1 and 2 and Charts 5 and 6.

GDP growth moderated from an average of 7.6% p.a. in 1990-99 to 4.9% p.a. in 2000-09 as Singapore progressed towards its technological frontier. Capital input was an important driver of growth in both periods, as shown by its dominant share in output growth. Within this category of input, the share of ICT capital has remained fairly stable at around 13%, while that of non-ICT capital declined from 44% to 33% in tandem with the weaker pace of non-ICT investment in the 2000s. Correspondingly, the average percentage point contribution of non-ICT capital fell sharply, from 3.3% points in 1990-99 to 1.6% points in 2000-09. The contribution of labour to output growth was stable at around 2.4% points over the two decades. As a share of output growth, labour input gained importance, reflecting strong gains in both employment and labour quality. (Table 1)

Given strong employment growth and a moderation in GDP growth over the two decades, average labour productivity growth slowed from 3.4% in the 1990s to 1.1% in 2000-09. The decomposition of productivity growth suggests that this can be attributed to a deceleration in capital deepening and a moderation in TFP growth. Improvements in labour quality have nevertheless helped to mitigate the slowdown in productivity growth, as shown by its much increased contribution in the 2000s. (Table 2)

The slowdown in TFP growth is more difficult to assess compared to the other sources of growth, as it is a residual in the growth accounting framework. Nevertheless, the literature indicates that TFP growth estimates are highly cyclical and may turn negative during recessions. The slowdown in TFP growth in the 2000s could thus be a result of the many cyclical shocks in the past decade, rather than of a structural downshift. Further, our estimates of TFP are expected to be lower than those computed by the standard growth accounting approach, which takes the residual difference between the growth of output and the contribution to growth of factor inputs without further adjustment to labour input to take into account quality changes. Such changes can, in fact, be quite significant in the case of Singapore, given the rapidly rising educational attainment of the labour force, as shown earlier.

Overall, there was a perceptible shift in growth drivers from capital to labour in the last two decades. The slower pace of productivity growth in 2000-09 was due to a sharp slowdown in both ICT and non-ICT capital deepening, as the economy utilised relatively more labour inputs for production. In addition, while labour input continued to be underpinned by increased hours worked, labour quality also became increasingly important.

Table 1
Sources of GDP Growth

	1990-99	2000-09
% Point Contribution		
GDP Growth	**7.6**	**4.9**
Capital Input	4.5	2.3
ICT Capital	1.1	0.7
Non-ICT Capital	3.4	1.6
Labour Input	2.2	2.4
Total Hours worked	2.1	1.9
Labour Quality	0.1	0.5
TFP	0.9	0.2
% Share		
GDP Growth	**100**	**100**
Capital Input	59	46
ICT Capital	14	13
Non-ICT Capital	44	33
Labour Input	30	50
Total Hours worked	28	39
Labour Quality	1.5	11
TFP	12	3.9

Source: EPG, MAS estimate
Note: Total hours worked refers to employment data. See footnote (3).

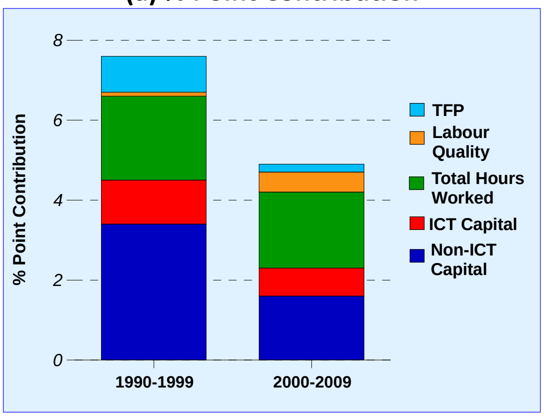
Table 2
Sources of Labour Productivity Growth

	1990-99	2000-09
% Point Contribution		
Labour Productivity Growth	**3.4**	**1.1**
Capital Deepening	2.4	0.4
ICT Capital	0.8	0.2
Non-ICT Capital	1.6	0.2
Labour Quality	0.1	0.5
TFP	0.9	0.2
% Share		
Labour Productivity Growth	**100**	**100**
Capital Deepening	73	32
ICT Capital	25	19
Non-ICT Capital	48	14
Labour Quality	3.2	50
TFP	24	18

Source: EPG, MAS estimates

Chart 5
Sources of GDP Growth

(a) % Point Contribution



(b) % Share

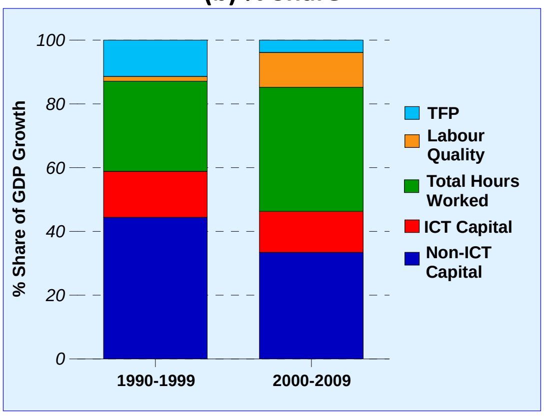
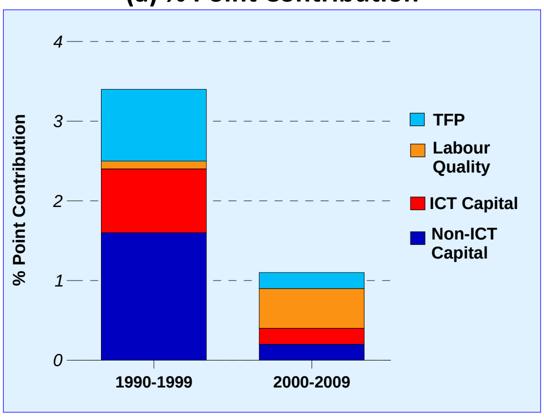
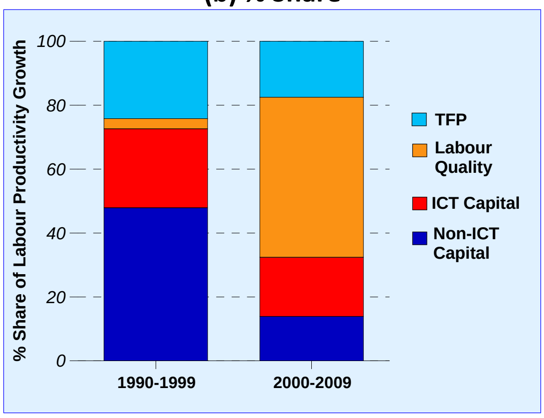


Chart 6
Sources of Labour Productivity Growth

(a) % Point Contribution



(b) % Share



Source: EPG, MAS estimates

A Global Comparative Perspective: The Role of ICT

In Table 3, Singapore's growth decomposition in the last two decades is compared to the average of the world and three separate country groupings comprising the G7, industrialised non-G7 countries, and developing Asia, reported in Jorgenson and Vu (2007). [12]

Over the period 1990-99, the contribution of ICT capital to Singapore's GDP growth was 1.1% points, surpassing the world average and all other country groupings. In 2000-08, ICT investment slowed in Singapore as it did in G7 economies as ICT penetration reached saturation levels, while the dotcom crash also reduced the hype associated with the new economy. The contribution of ICT, however, continued to rise in developing Asia and in the world as a whole.

In terms of its share in GDP growth, the contribution of ICT has been relatively stable at about 13% for Singapore but lower than for the industrialised groupings in the two periods. In comparison, the share of ICT increased substantially in developing Asia from 3.6% in 1990-99, to 6.3% in 2000-08.

Table 3
Contribution of ICT Capital and Non-ICT Capital to GDP Growth

		Singapore*	World	Industrialised Countries		Developing Asia
				G7	Non-G7	
% Point Contribution						
1990-99	GDP Growth	7.6	2.8	2.5	2.7	6.7
	Capital Input	4.5	1.5	1.5	1.3	2.9
	ICT	1.1	0.40	0.54	0.47	0.24
	Non-ICT	3.4	1.1	1.0	0.86	2.7
	Other Sources	3.1	1.3	0.95	1.4	3.8
2000-08	GDP Growth	4.9	3.9	2.0	2.7	7.3
	Capital Input	2.3	1.6	1.2	1.5	2.9
	ICT	0.70	0.43	0.45	0.47	0.46
	Non-ICT	1.6	1.2	0.72	1.1	2.5
	Other Sources	2.6	2.3	0.84	1.2	4.4
% Share						
1990-99	GDP Growth	100	100	100	100	100
	Capital Input	59	54	62	49	43
	ICT	14	14	22	18	3.6
	Non-ICT	44	40	40	32	40
	Other Sources	41	46	38	51	57
2000-08	GDP Growth	100	100	100	100	100
	Capital Input	46	41	58	57	40
	ICT	13	11	23	18	6.3
	Non-ICT	33	30	36	39	34
	Other Sources	54	59	42	43	60

Source: Jorgenson and Vu (2007) with updated data
*2000-09 estimates are used for Singapore.

[12] The average figure is weighted by GDP in PPP terms.

Labour Productivity Projections in the Medium Term

Analytical Framework

In this final section, the growth accounting framework is used to project Singapore's productivity growth in 2010-19. Specifically, from equation (3), projections for labour productivity growth can be derived from assumptions about labour quality, TFP and capital deepening. Jorgenson and Vu (2009) augmented this equation by defining capital services K as a function of the quality of capital K_Q and the reproducible capital stock K^s, thus obtaining the following model:

$$\Delta \ln y = \left(\frac{\bar{v}_K}{\bar{v}_L}\right)\Delta \ln K_Q + \left(\frac{\bar{v}_K}{\bar{v}_L}\right)\tau + \Delta \ln L_Q + \left(\frac{1}{\bar{v}_L}\right)\Delta \ln A \quad (8)$$

where τ represents the gap between the growth rates of capital stock K^s and Y. (See Appendix for more details.)

Accordingly, medium-term labour productivity growth depends on the quality of labour and capital, TFP growth and the gap between capital stock growth and output growth.

Baseline Assumptions

Table 4 outlines the baseline assumptions for the various components in equation (8) over the period 2010-19. Average labour quality growth is projected at 0.7-0.9% p.a., which is slightly lower than the average growth of 1.0% in the last decade.[13] This assumes that labour quality continues improving as a result of ongoing policies to enhance the skills in the workforce. It projects Singapore's share of the resident population aged 25-64 with tertiary education to rise to 36% by 2020, almost 6% points higher than in 2008 and comparable to what Finland achieved in 2007.

Also, the shift towards higher quality capital stock is expected to proceed at a slightly faster pace of 0.2-0.4% p.a. as compared with the last decade, reflecting a renewed interest by businesses to invest in better equipment and machinery, further supported by the recent fiscal incentives in Budget 2010. The assumed growth in capital quality is, however, likely to be considerably slower than in the 1990s, as the economy is now closer to its technology frontier.

Our baseline assumption for τ is derived from an assessment of the capital-to-output ratio (K^s/Y). Over the period 2000-09, capital accumulation proceeded at a slower pace relative to output growth. In comparison, the addition to capital stock in the current decade is expected to outpace GDP growth by about 0.2-0.4% point, in line with a gradual pickup in investment in machinery and equipment. This is due to an expected recalibration of the optimal capital-output mix in production in view of the slower growth in the workforce and shift towards higher productivity and technology-intensive activities, as well as the fiscal incentives to support capital investments provided in the recent Budget. The projections also draw on cross-section country experiences. Jorgenson and Vu (2009) estimated that the value of τ for 122 economies over the period 2000-06 averaged around 0.2%. In the more developed economies, such as the US and Korea, τ has also been positive, averaging around 1% in the last decade. The inference is that there is scope for capital stock accumulation to outpace output growth even in a post-industralisation phase of development.

13 The strong labour quality growth over the period 2000-09 would have been accentuated by cyclical gains in wages and inflows of skilled foreign workers during the robust economic expansion in 2005-08. For the purpose of medium-term projections, some moderation in average labour quality growth is assumed in this decade.

Lastly, TFP growth is assumed to be within the range of 0.4-0.7% p.a. in the period 2010-19. This is consistent with the growth experiences of OECD economies and the projections in Jorgenson *et al*. (2008).[14]

Results

These assumptions are substituted into equation (8) to derive productivity growth projections.[15] The results suggest an estimate for labour productivity growth of between 2% and 3% on average per annum for the period 2010-19, compared to 3.4% and 1.1% in the 1990s and 2000s, respectively.

According to the Report of the Economic Strategies Committee (ESC), labour force growth is expected to slow to an average of 1-2% per annum in 2010-19, from an average of 4% in the past two decades.[16] Combining this with productivity growth assumptions produces a medium-term potential GDP growth of 3-5% for the Singapore economy over the next decade.

Table 4
Average Annual Growth Rates for Sources of Labour Productivity Growth

Sources of Labour Productivity Growth	Historical (%)		Assumptions (%)
	1990-99	2000-09	2010-19
Labour Quality	0.2	1.0	0.7 – 0.9
Capital Quality	0.9	0.2	0.2 – 0.4
$\tau\ \left(\Delta \ln K^s - \Delta \ln Y\right)$	0.5	-0.5	0.2 – 0.4
TFP	0.9	0.2	0.4 – 0.7
Average labour productivity growth	3.4	1.1	2.0–3.0

Source: EPG, MAS estimates

14 For example, the scenario analysis in Jorgenson *et al*. (2008) assumes an average of 0.5-0.95% for the US economy, while the EU KLEMS growth decomposition of selected OECD countries (US, Sweden, Netherlands, Korea, Germany, Finland, France and Ireland) over the period 19960-2005 suggests an average TFP growth of 1%.

15 Factor shares are assumed to be those in 2008.

16 The Economic Strategies Committee (ESC) was established in May 2009 by the Prime Minister to chart the course for Singapore's economic development over the next decade. Chaired by the Minister for Finance, the ESC completed its work in February 2010.

Sum-up

The Singapore economy has performed well over the past two decades, notwithstanding the many external shocks it has encountered. Economic progress has been achieved through the effective accumulation and deployment of capital and labour inputs, as well as positive TFP growth. Going forward, there is potential for higher quality, but slower, growth than in the past, with a mix of factors of production that can maximise the potential of ICT and human capital.

The decline in labour productivity growth in recent years suggests that priority should now be given to raising labour productivity. This can be achieved in a number of ways. First, there is further scope for Singapore to leverage on ICT as a horizontal enabler to support capability-driven growth. There are, after all, positive spillovers when production is re-organised around capital goods that embody new technology and capabilities. Moreover, the use of ICT in education and training could facilitate the upgrading of labour skills, further augmenting human capital.

Second, to fully exploit the potential of ICT investment, there is a need to better harness the productivity gains from ICT investment by complementing it with the right amount and the right type of human capital. Micro-level studies have highlighted the importance of organisational complements, such as new business processes, new skills, and new organisational and industry structures, to secure the full benefits of ICT investment. However, organisational innovations such as these can take some time to pay off. (See Box C for more details.)

At a broader level, there is a case for a higher investment growth rate, particularly in machinery equipment and software, to ensure that the Singapore economy continues to converge to its technology frontier. Increasing the capital intensity of production is also, arguably, the most direct policy lever to lift productivity growth across a range of industries.

On the labour front, there has been a large increase in physical labour input in recent years, aided by an inflow of foreign workers. There is also no doubt that the quality of labour in the Singapore economy has improved significantly over time, providing an important fillip to growth.

Following the recommendations of the ESC, the government has put in place several initiatives in the FY2010 Budget that should support the restructuring of the Singapore economy to enhance its productivity over the medium to long term. These include various tax benefits, grants and training subsidies to help companies and workers to invest in productivity, to innovate and to deepen their skills and expertise. (See Section 3.6 of this *Review* for more details on the budget measures.) Such measures should yield significant benefits over the next decade.

Box C
How Organisational Practices can be Complementary to IT Investment

Introduction

The strong links between investment in IT and the adoption of complementary organisational practices at the firm level, such as new business processes, new skills, and new organisational and industry structures, are well-documented in the literature and recent studies in this area have increasingly used formal statistical approaches to determine the magnitudes of these observed relationships. This box considers some key results in this area and highlights a few relevant case studies.[1/]

Large-sample Empirical Studies

Earlier work by Milgrom and Roberts (1990) emphasised that firms typically need to adopt technology as part of a system of mutually reinforcing organisational changes in order to be successful. Using data from 36 steel-finishing lines in 17 different companies, Ichniowski *et al*. (1997) expounded on this by examining the relationship between complementarities and productivity. Measuring the effects of different workplace practices on productivity and product quality, they found that clusters of workplace practices have significant positive effects on productivity, whereas changes in individual work practices have little or no impact.

Bresnahan *et al*. (2002) reached similar conclusions from a firm-level analysis of about 300 large American firms between 1987 and 1994. Their findings suggest that the increased use of IT, together with changes in organisational practices and products and services, formed the basis for skill-biased technical change that necessitates more skilled labour.

Using an extensive database comprising close to 6,000 British firms across all industries over the period 1998-2000, Crespi *et al*. (2007) obtained lower returns to IT after controlling for complementary organisational assets, suggesting that some of the IT-related boost in productivity indeed came from organisational factors.

Furthermore, Brynjolfsson and Hitt (2003) show the long time lag before investment in IT yields substantial returns because of the need for accompanying organisational changes. Using data from 500 large firms, they found no significant difference between the one-year returns to IT and ordinary non-IT capital. Over a longer period (5-7 years), however, the productivity and output contributions of the same technology investment were up to five times larger due to the time required for the complementary investment in human capital and business process reorganisation to come to fruition.

Specific Case Studies

Apart from empirical evidence discussed earlier, there are also numerous case studies of companies that have successfully reaped the benefits of their investments in IT through the adoption of new workplace practices and strategies.

Brynjolfsson *et al*. (1997), for example, recount the story of Macromed, a large medical products manufacturer which made a large investment in computer integrated manufacturing. The new system failed to improve productivity initially as line workers still retained many elements of their habitual work practices. For instance, with the old equipment, improving productivity meant avoiding stopping the machines for product changeovers. This ironically negated the flexibility of new machines and as a result, created large work-in-process inventories. Eventually, new equipment was introduced successfully in a Greenfield site with young employees who were relatively unencumbered by knowledge of the old practices.

[1/] The main references for this box are Bloom and Reenen (2010), Brynjolfsson and Hitt (2000) and Brynjolfsson and Saunders (2010).

A similar outcome was achieved by Baxter in the US when they launched the ASAP system to allow hospitals to electronically order supplies directly from wholesalers. The system was originally designed to reduce the costs of data entry. However, once Baxter computerised the procurement process and had data available on the inventory levels of hospitals, this introduced changes to the entire supply chain operation, from designing stockroom space, to setting up computer-based inventory systems and providing automated inventory replenishment. The combination of the technology and the new supply chain organisation substantially improved efficiency for both Baxter and the hospitals.

Other examples include Dell Computer and Amazon. Dell implemented a web-based system to sell its products and provide technical support, thus building closer relationships with its customers. This was complemented by systems and work process changes that emphasised 'just-in-time' inventory management, build-to-order production systems, and tight integration between sales and production planning. Such a customer-driven build-to-order business model provided Dell with a significant cost advantage over its competitors.

In a similar vein, web retailers, such as Amazon, provided personalised recommendations to visitors and allowed them to customise numerous aspects of their shopping experiences. Merely providing Internet access to a traditional bookstore would have had relatively little impact on the firm's productivity without the cluster of other necessary changes implemented at the same time.

Management Practices and Productivity

More broadly, Bloom and Van Reenen (2010) highlighted the importance of management practices in explaining large differences in productivity between firms and countries. Using data collected from 6,000 firm interviews in 17 countries, they systematically measured management practices across firms, industries and countries according to three broad areas (namely, monitoring, targets and incentives).

Regressing GDP per capita (a proxy for productivity differences) against the scores for management practices across the sample of countries yields a robust fit. At the firm level, they found that higher management scores are strongly correlated with better firm performance in terms of productivity, profitability, growth rates, survival rates and market value. The authors noted several factors that influenced the quality of management. Product market competition played a critical role in increasing aggregate management quality, as badly-run firms exited more speedily and incentives to improve management practices could be larger in more competitive markets. Taxes and other distortive policies that favour family-run firms also appeared to hinder better management, while general education and the presence of foreign multinationals were important in improving management practices.

Sum-up

Research in this area suggests that firms need to pay greater attention to organisational and management practices in light of their impact on productivity. Apart from introducing new and better equipment or software to enable workers to create more value, there is also a need to train and upgrade employees, increase spending on R&D or its commercialisation, reorganise the workplace to eliminate unnecessary processes, and build a culture that motivates employees. At the country level, governments need to establish measures and incentives that support such efforts. In this regard, Singapore has made an important step in this direction by recently establishing a National Productivity and Continuing Education Council to drive efforts to raise productivity at the individual, enterprise and sector-levels, as well as to develop a world-class national continuing education and training system.

Appendix
Analytical Framework for Projecting Labour Productivity Growth

This appendix provides a brief derivation of equation (8), which is used to project Singapore's labour productivity growth. The approach is based on recent work by Jorgenson and Vu (2009).

From equation (3), both ICT and non-ICT capital services inputs are combined to obtain the composite overall capital services K, with a corresponding income share given by $\bar{v}_K$ as follows:

$$\Delta \ln y = \bar{v}_K \Delta \ln k + \bar{v}_L \Delta \ln L_Q + \Delta \ln A \qquad (8)' \; ,$$

where y is labour productivity (ratio of total output Y to total labour hours worked H), k refers to capital deepening (ratio of capital services K to total labour hours worked H), L_Q is the labour quality index, and A is TFP.

To obtain equation (8), overall capital services K is further broken up into two subcomponents, and another measure, τ, is introduced to capture the gap between the growth rate of capital stock and output. The relevant equations for K and τ are given by

$$K = K_Q K^s \qquad \text{and} \qquad \tau = \Delta \ln K^s - \Delta \ln Y,$$

where K_Q is the quality of capital and K^s represents the reproducible capital stock. Substituting the two equations into equation (8)' results in the following:

$$\Delta \ln y = \bar{v}_K \left(\Delta \ln K_Q + \Delta \ln K^s - \Delta \ln H \right) + \bar{v}_L \Delta \ln L_Q + \Delta \ln A \qquad (8)''$$

Rearranging equation (8)'' leads to the Jorgenson and Vu (2009) model in equation (8):

$$\Delta \ln y = \left(\frac{\bar{v}_K}{\bar{v}_L} \right) \Delta \ln K_Q + \left(\frac{\bar{v}_K}{\bar{v}_L} \right) \tau + \Delta \ln L_Q + \left(\frac{1}{\bar{v}_L} \right) \Delta \ln A$$

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