Decomposing China's GDP Growth:

The importance of productivity and investment rate changes in explaining output per worker growth in China?

By

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Abstract

Since 1960 China's investment rate has more than doubled, from 20% of GDP to over 40%. This rise in the investment rate is often argued to be the key reason for China's spectacular growth rate of output per worker. This paper shows that holding the investment rate fixed at the pre-1978 level, only about 10% of the increased growth rate in China is explained by the increased investment rate. The rise in productivity that occurred during economic reforms over this period explains the vast majority of the increased growth rate of output per worker. This paper uses a counterfactual analysis developed within a standard Neoclassical model, and the results are robust to standard variations in the parameter values.

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1. Introduction

Understanding what contributes to economic growth is arguably the key to understanding economic development. For developing countries, understanding what policies and procedures will result in economic growth is important in allowing them to catch up to the developed world. Over the past several decades, China has experienced impressive economic growth when compared to global standards (Bosworth and Collins 2007). Since 1965 China has had an average output per worker growth rate of over 6.5%, and over the past decade has consistently been above 9% compared to the world growth rate averaging less than 3%[1]. Understanding the contributing factors that have led to this high growth rate will provide a guide for other countries trying to emulate China's success.

Along with output per capita, China's investment rate measured as a percentage of GDP, has undergone a dramatic increase, rising from around 20% in the mid 1960's to more than 40% in recent years. While not necessarily the world leader in this aspect, this investment rate is quite high compared to most developed economies; the United States, United Kingdom, and Canada for example, all have investment rates of around 20%. This increase in the investment rate is one obvious candidate which could explain a large portion of China's growth in output per worker. Heckman and Yi (2012) conclude that it is the high level of capital investment that caused the high growth rates in China. Chow and Li (2002) and Woo (1996) also conclude that the high rates of investment would allow China's growth to remain high and at targeted levels as has been observed in the data.

[1] Data is taken from the World Bank - GDP per capita growth (annual %).

From a Neoclassical growth perspective, attributing such an important role to investment is surprising. These models show that productivity growth is the main, and in some cases only, factor in determining economic growth in the long run. These models tend to credit investment increases as having short run effects on levels of output, but little to no effect on long run rates of economic growth. In an analysis on the direction of causality between investment and output growth, Blomstrom et al. (1996) come to the conclusion that investment is not a key component leading to economic growth. Using regression analysis they conclude that fixed capital formation is not a primary source of output per capita growth.

Using the decomposition method of Hall and Jones (1999) with Chinese data shows that less than 1% of the growth from 1965 to 2010 is explained by rising investment levels. The growth is almost entirely credited to increases in productivity. One potential limitation of the Hall and Jones approach is that it relies on the assumption that the economy is in a steady state. With a developing country such as China, this may be a spurious assumption to make. Loosening the restriction of a steady state may allow a greater portion of growth to be explained by increases in the investment rate.

In this paper I use a variation on the Neoclassical growth model, which removes the restriction of a steady state. In particular, I use a model developed by Robertson (2012) to examine the growth in China. This model allows for the calculation of the effects of both changes in the growth rate of productivity and the investment rate on the growth rate of output per worker while transitioning to the steady state. This is done by creating counterfactual series of output per worker growth with the rate of investment and the productivity growth rate held constant. Comparing these counterfactual series with observed data allows for the calculation of the portion of the rising growth rate which can be attributed to rising investment rate and the portion attributed to rising productivity growth. This decomposition shows that the increased investment rate has played a minor role in the growth of output per worker, resulting in only about 10% of the increased growth rate since 1978. In the more recent period since 1994 the rising investment rate may have played a stronger role, explaining perhaps as much as 2/3 of the increased growth rate of output per worker over this period. While this result may appear quite strong at first glance, the nominal increase in the growth rate over this period was relatively small, meaning investment is still only explaining a small fraction of total growth. The model shows that a rising investment rate has had some contribution to China's rising output per worker growth, but remains of secondary importance to the productivity increases the country has achieved since the beginning of its economic reform period.

This paper proceeds as follows: Section 2 briefly examines the growth literature and relevant institutional changes in China. This section also explains the relevant data. Section 3 applies standard Neoclassical growth accounting to the Chinese data. Section 4 outlines the methodology used in creating the counterfactual series. Section 5 provides more detailed information about the data. Section 6 contains the results and analysis of the counterfactual series created, and finally Section 7 concludes.

2. Literature Review and Institutional Details

2.1 Literature Review

This paper uses a form of growth accounting to determine if the rising investment rate has been a significant factor in China's rising growth rate of output per worker. The growth accounting literature starts with Robert Solow's (1957) influential paper. Solow decomposes the growth of aggregate output into the components contributed by capital, labour, and productivity and shows that increases in productivity have been the most important source of economic growth. Numerous additional factors have been considered since this paper to explain differences in growth. Mankiw, Romer, and Weil (1992) do a similar decomposition using differences in human capital in addition to physical capital to explain the differences across countries. Hall and Jones (1999) use institutional differences to explain differences in economic growth and productivity in countries. They use an instrumental variables approach to measure the institutional stability of countries and show that the differences in institutions are able to explain a great deal of the differences in cross-country output.

Peter Robertson (2000, 2012) uses a method of growth accounting employing counterfactuals as a means to examine growth in East Asia and India. He examines the theory that the growth in these countries was driven by investment, but concludes that the investment was of secondary source in explaining the growth behind productivity. For India, over the period from 1950 to 2007 the investment rate increased by nearly four times from 10% to 40% of GDP. Hall and Jones' approach attributes less than 1% of the growth in India over this period to the higher investment rate. Conversely, Robertson's models shows that about 30% of the growth over this period can be attributed to the higher investment rate. Robertson's model still shows productivity increases are the primary source of growth, but are less important than in Hall and Jones approach. This difference in results arises from Hall and Jones imposing the restriction that the economy is in a steady state, which is not a feature in Robertson's model.

2.2 Institutional Changes

China has gone through a similar change to its investment rate in the latter half of the twentieth century. While not quite as dramatic as the four-fold increase in India, the investment rate has risen from below 20% in the 1960s to over 40% currently. Sachs and Woo (2001) show that the period in which China went through a great deal of its important market reforms began in 1978 and ended in 1994. It is this around this reform period which much of the analysis in this paper will take place. Counterfactual time series are created from both the beginning and the end of these economic reforms.

It is well known that China has had some of the most spectacular growth in gross domestic production (GDP) over the past half century. Figure 1 shows the logged GDP per worker, log(y), in China from 1965 to 2010. The series is adjusted using a Hodrick-Prescott (HP) filter to smooth the data and see the underlying trend. Further information on the HP filter is found in the Appendix. From this smoothed series, the increase in the growth rate over time is more clearly visible. As the series is measured in logarithms, the slope of the curve can be interpreted as the growth rate over time. The slope is increasing over time showing that the growth rate has been rising. Figure 2 shows the same data in terms of the yearly growth rates.

Once again the series has an HP filter applied and shows that the growth rate has increased from less than 5% in the period prior to 1978 to just over 10% in 2010.

Figure 1: Log GDP per worker (log(y))

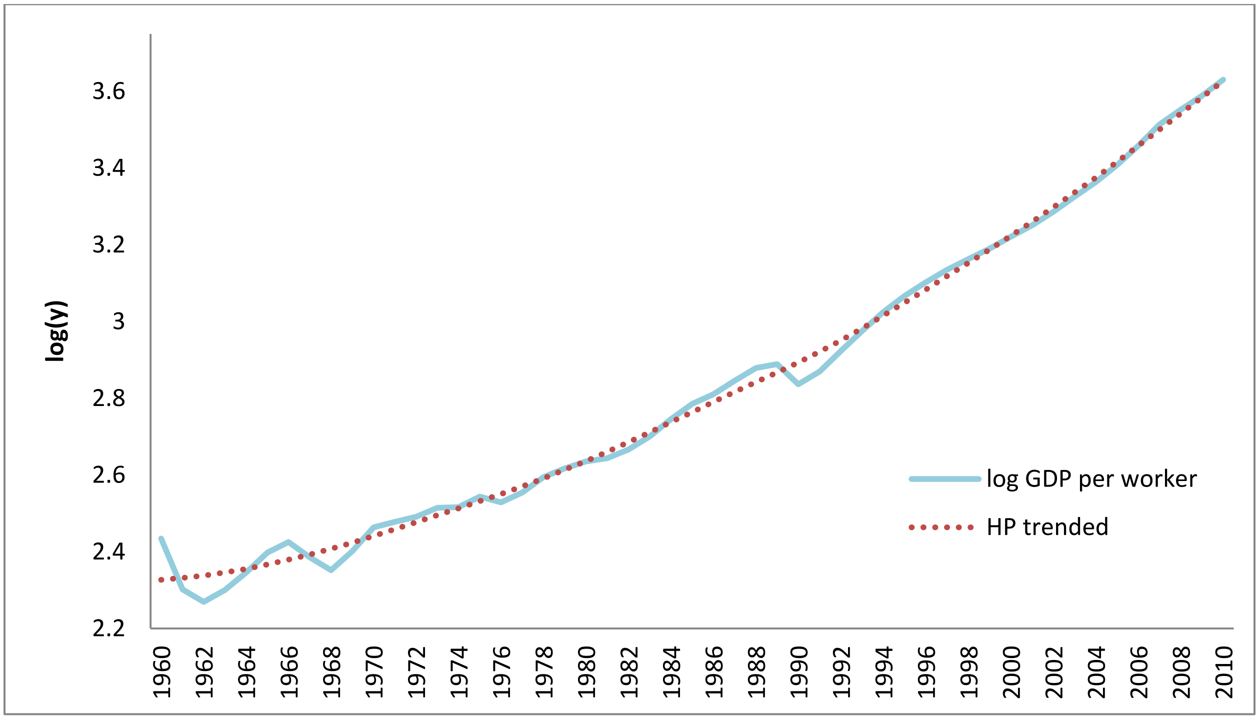


Figure 2: Output per worker Growth Rate

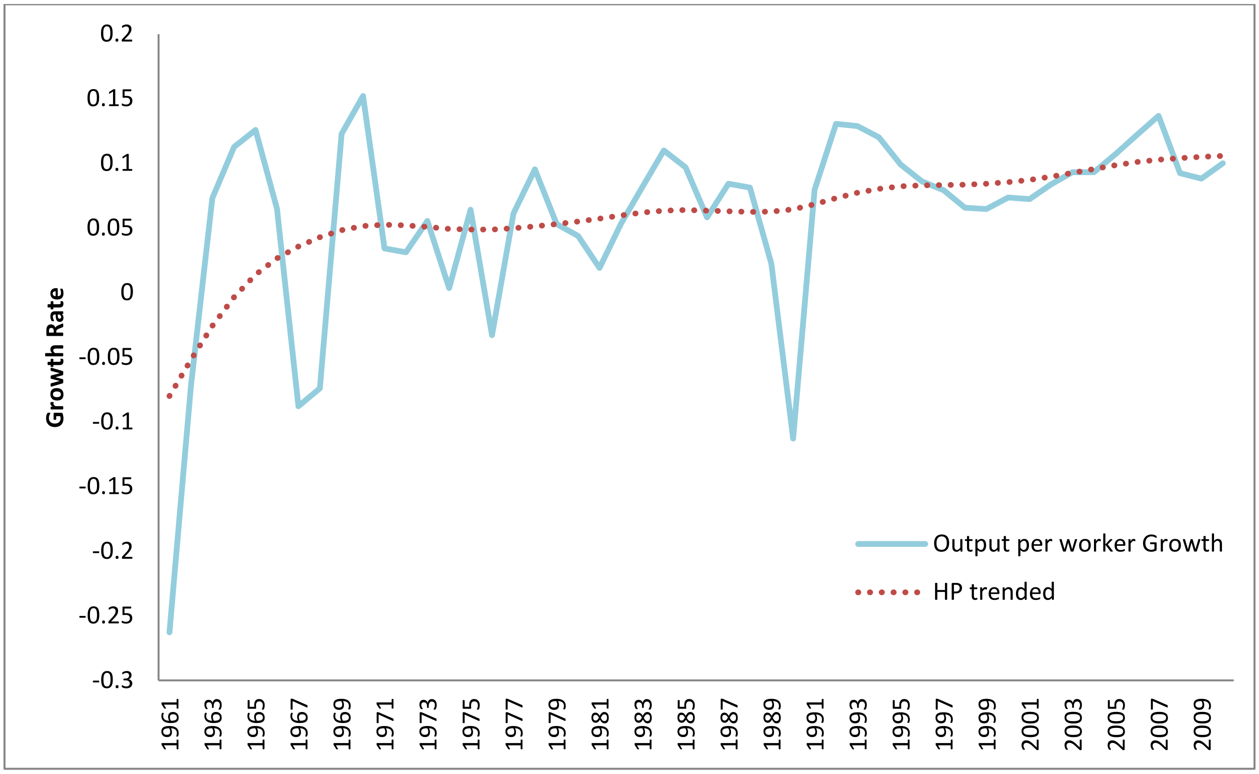


Figure 3 shows the investment level for China measured as a fraction of GDP. The increase is readily apparent over the 50 year period, however applying the HP filter to the series shows that the investment level was increasing prior to the economic reforms in the late 1970s, then held relatively constant during this period, and once again began to rise after the reform period. This paper will examine how growth would have proceeded in the absence of the rising investment rate.

Figure 3: Investment Rate as a Fraction of GDP

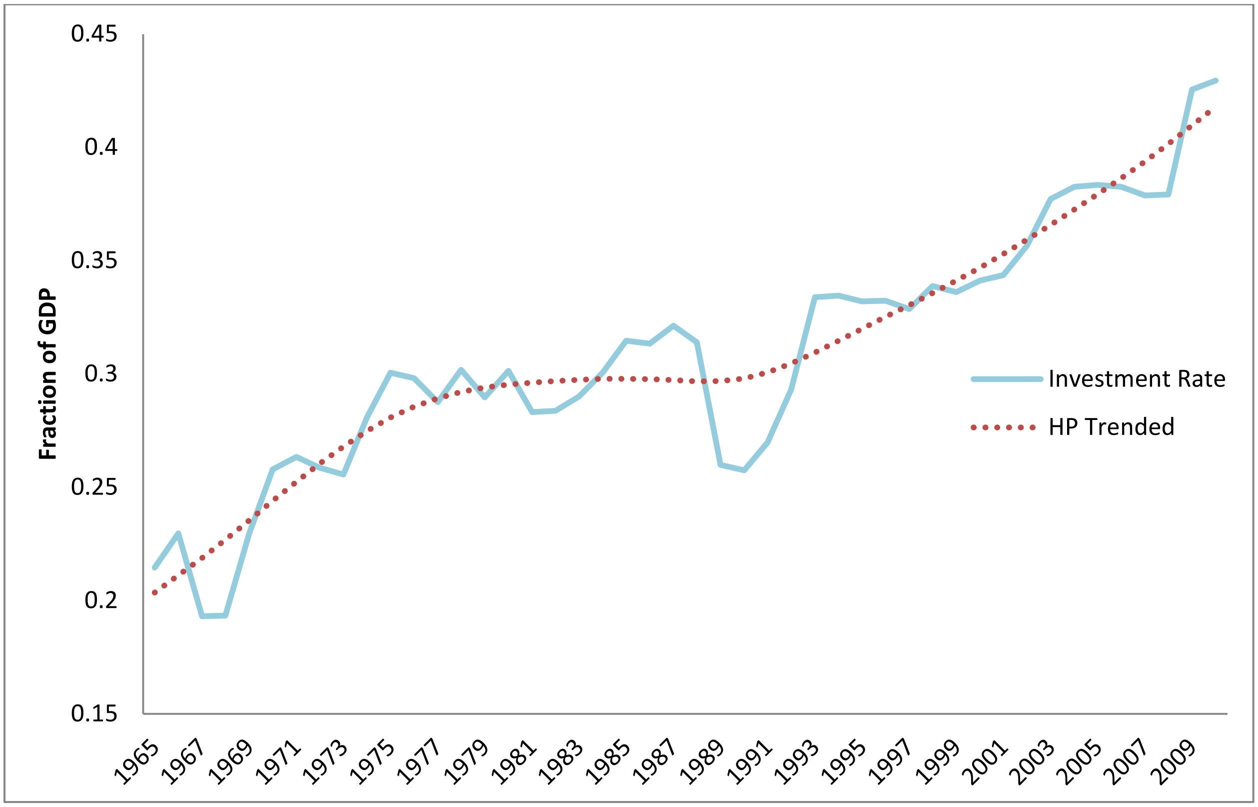
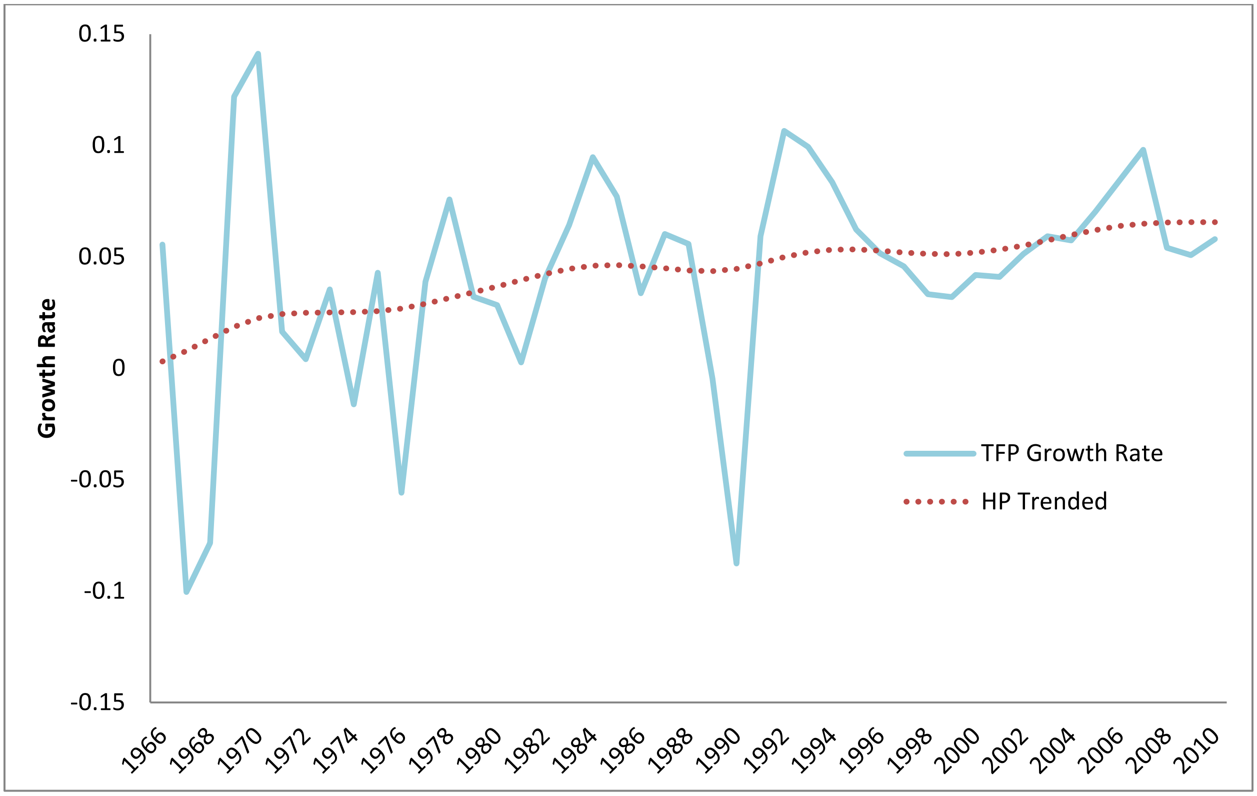


Figure 4 shows the total factor productivity growth rate for China over the period from 1965 to 2010. This series is quite volatile ranging between -10% and 15%. Once again when the HP filter is applied to the data we can see the overall trend has been that productivity growth has increased from close to zero in the beginning of the period rising up nearer to the 6% level. The rise in this productivity growth occurs more rapidly at first, rising up to roughly 5.5% by the end of the economic reform period in 1993 and only increasing by another 1% over the remaining 17 year period.

Figure 4: Total Factor Productivity Growth Rate



3. Neoclassical Growth Models

3.1 Growth Accounting Decomposition

The basic growth accounting decomposition allows for the growth in output to be broken down into the components from different factors of production. The analysis starts with the standard Cobb-Douglas production function with constant returns to scale:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \tag{1}$$

where Y_t is output, K_t is capital, L_t is labour, A_t is productivity measured in units of output, and α is the output elasticity on capital, also known as capital's share. In order to examine the output in per worker terms, we use the variables $y_t = Y_t/L_t$ and $k_t = K_t/L_t$ to give measures of output per worker and capital per worker respectively. Solving the previous equation in terms of these per worker variables gives the following:

$$y_t = A_t k_t^{\alpha} \tag{2}$$

From (2) we can calculate productivity from the observed values of output and capital per worker by rearranging the equation to $A_t = y_t/k_t^{\alpha}$. Taking the logarithm and time derivatives of both sides of (2) allows the growth rate in output per worker to be decomposed into the portions attributable to productivity and the portion attributable to capital per worker. The result shows that growth of output per worker is equal to the growth of productivity plus the growth of capital per worker times capital's share of output.

Table 1 shows the basic growth accounting results using the Chinese data. All results reported in the table are average annual growth rates for the stated period. Column 1 shows the growth rate of output, followed by growth of labour in column 2, output per worker in column 3, and capital per worker in column 4. Columns 5 and 6 contain the contribution to growth caused by capital and total factor productivity respectively. This decomposition shows that capital has increased in importance since the end of the Chinese reform period, explaining a greater portion of the growth since 1994 than it had during the 1978-1993 period. This increasing importance of capital in the post reform period provides support to the hypothesis that a rising investment rate leads to a rise in output per worker growth.

Table 1: Growth Accounting Results (α=1/3)

Growth Accounting Results						
	Output	Labour	Output per Worker	Capital per Worker	Capital Contribution	Productivity Contribution
1965-2010	9.11	2.25	6.79	7.05	2.35	4.44
1965-1977	6.87	2.74	4.00	4.80	1.60	2.40
1978-1993	9.87	3.42	6.41	5.17	1.72	4.68
1994-2010	10.12	0.77	9.28	10.40	3.47	5.81

Hall and Jones Decomposition

An alternative method to examine the growth data is to apply the type of decomposition that Hall and Jones (1999) use which relies on steady state equilibrium so that aggregate variables grow at the same rate, and therefore the capital output ratio remains constant. This is because in the steady state both K and Y grow at the same rate as technology. Hall and Jones use an alternative approach to represent productivity measuring it in terms of labour units rather than output, using $B^{1-\alpha} \equiv A$. Using this alternative specification of productivity transforms (2) to:

$$y_t = B_t^{1-\alpha} k_t^{\alpha} \quad (3)$$

This can then be rearranged to give:

$$y_t = (k_t / y_t)^{\alpha/(1-\alpha)} B_t \quad (4)$$

Using (4) we can examine two types of changes that would lead to output growth. The first is a change in productivity levels that will affect B but leave the capital output ratio unchanged. The second is an increase in investment rate which will change the capital-output ratio but keep the productivity term B unchanged.

Applying the Hall and Jones method to data for China shows similar results to those found by Robertson (2012) when he applied the method to Indian data. The results can be seen in Table 2. Changes in the capital/output ratio from changes to the rate of investment explain less than 1% of overall growth. This very low contribution from investment seems implausible. The key assumption in this case is that the Hall and Jones approach assumes a steady state so that the growth rate of productivity is the same at both the beginning and end of the period. For China this assumption likely does not hold, particularly given the drastic economic changes the country has undergone.

The problem with the assumption of a steady state is that it assumes the growth rate of productivity remains unchanged. The increasing growth rate of productivity as opposed to increased levels of productivity has different effects. While a discrete change in the level of productivity has no effect on the capital-output ratio, the increasing growth rate will actually cause the ratio to fall. Because of this the increases to the productivity ratio caused by increasing investment levels appears to be cancelled out by the decreases caused through a rising productivity growth rate. Thus, we need to examine the data using a method which does not rely on the steady state, allowing for a changing growth rate of productivity as seen in Robertson (2012).

Table 2: Decomposition based on Hall and Jones

Hall and Jones Decomposition				
	Output per worker	capital output ratio	investment rate contribution	productivity in labour units
1965-2010	9.114	0.006	0.003	9.112
1965-1977	7.273	0.014	0.007	7.266
1978-1993	9.900	-0.002	-0.001	9.901
1994-2010	10.490	0.007	0.004	10.486

4. Methodology

Using simulations I create counterfactual series for how capital and output would have evolved in the absence of changes to the investment level and changes in the productivity growth rate. Creating the series involves a dynamic three equation system:

$$K_{t+1} = K_t + I_t - \delta K_t \quad (5)$$

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \quad (6)$$

$$I_t = s_t Y_t \quad (7)$$

Equation (5) shows the capital accumulation method. Capital is determined based on the capital stock from the previous period and the amount of new gross capital invested (I_t) minus a factor of depreciation, where δ is the rate of depreciation. Equation (6) is the Cobb-Douglas production function with constant returns to scale and a capital share α. Equation (7) shows that the level of new gross capital invested is equal to an investment rate (s_t) times the level of output. For the data, levels of K_t, Y_t and L_t are all observed measures of the capital stock, the

GDP, and the labour force respectively. From (7) we can see that $s_t = I_t/Y_t$ and can extrapolate the actual yearly investment rate that was experienced in the country from the observed levels of investment and GDP. In the system K_{t+1}, I_t, and Y_t are all determined endogenously, while δ, A_t, s_t, and L_t are all exogenous to the system. From the actual observed data on capital, investment, GDP, and labour the levels of s_t and A_t can be determined over the actual growth path of the system.

There will be 2 groups of counterfactual series produced, one beginning at the start of the reform period in 1978, and a second examining the post reform period beginning in 1994. The majority of the rise in the investment rate took place in the latter period beginning in 1994. For this reason it is of interest to see the effects that the changes in the investment rate have had on output per worker growth over the two periods separately.

5. Data

In this paper I have collected data for the labour force, capital investments, and GDP in China over the period from 1965 to 2010. Capital stock levels are calculated using a perpetual inventory method, and the initial capital stock level is calculated using a fairly standard approach of estimation using a three year average taken from Nehru and Dhareshwar (1993). A more detailed explanation of this approach is found in the Appendix.

The labour force data was collected from the China Data Center (CDC) out of the University of Michigan[2]. This labour force series is the total number of employed workers in the country for the given year. While the data dates back to 1960, there appears to be a change in the method of recording, or some form of discrepancy starting from 1990 onward. The data for labour force size is available elsewhere for the period 1990 to 2010, and matches well with the data collected here from the CDC. Between 1989 and 1990 the labour force increases by 17%, a much larger jump than any year previously or afterward. Other than this one discrete jump the labour force growth rate remains bounded between -1.1% and 4%. To account for this discrepancy and attempt to correct for it I also create an artificial labour series prior to 1990, but the results remain relatively unchanged. The Appendix contains more detailed information on this artificial labour series and the method used to compute it.

The data on GDP and investment are both taken from the World Bank National accounts data and the OECD National Accounts Data files[3]. The measure used for investment in this paper is gross fixed capital formation. This measure captures any increases in land improvements, capital expenditure on plant machinery and equipment purchases, as well as the acquisition of valuables. The values are all measured in constant US dollars for the year 2000. The values are converted from the local currency using the official nominal exchange rate from the year 2000. One potential limitation of this measure is that it shows only the

[2] The China Data Center has National Statistics on Population and Employment. Under the Employment, Staff and Workers of China the data on the yearly total number of employed persons can be found. The data is also further separated by sector and industry.

[3] The data was collected from IndexMundi, which is a database that amasses information on various economic and demographic variables from numerous databases.

relative wealth of the country, but not necessarily the standards of living which can be captured when values are adjusted for relative purchasing power parity (PPP).

6. Results

The counterfactual analysis involves holding the investment rate and/or the productivity growth rate constant. In Figure 3 the investment rate is quite volatile around the key years of interest in 1978 and 1994. For this reason the investment rate given by the HP filtered path, is chosen. For the year 1978 this gives a rate of 29.2% as the investment rate to hold constant. For the productivity growth rate the series is even more volatile, so again the HP filtered series is used to choose the productivity growth rate of 3.15% for 1978 as the rate to hold constant. When examining the growth simulations beginning instead at the end of the reform period in 1994, using the same process an investment rate and productivity growth rate of 30.9% and 5.3% respectively are chosen.

Figure 5 shows the results of these counterfactual growth simulations starting in the year 1978 at the beginning of China's economic reforms. The three counterfactual series examine how the growth would have proceeded by holding the investment rate constant at the 1978 level of 29.2% and/or holding the productivity growth rate constant at 3.15%. The first simulation is the base case where both values are held fixed. The second holds the productivity growth rate fixed while allowing the actual investment rate to fluctuate as in the observed data. The third does the opposite, holding the investment rate constant while allowing the productivity growth rate to follow the observed data. The remaining series is the actual growth path of output per worker over the period from 1978 through 2010. All the series are measured in log of output per worker. From the figure we see that holding the investment rate constant over this period results in only a slightly lower growth path for the log of output per worker. Holding productivity growth constant produces a much more dramatic decrease.

Figure 5: Growth Simulations beginning in 1978

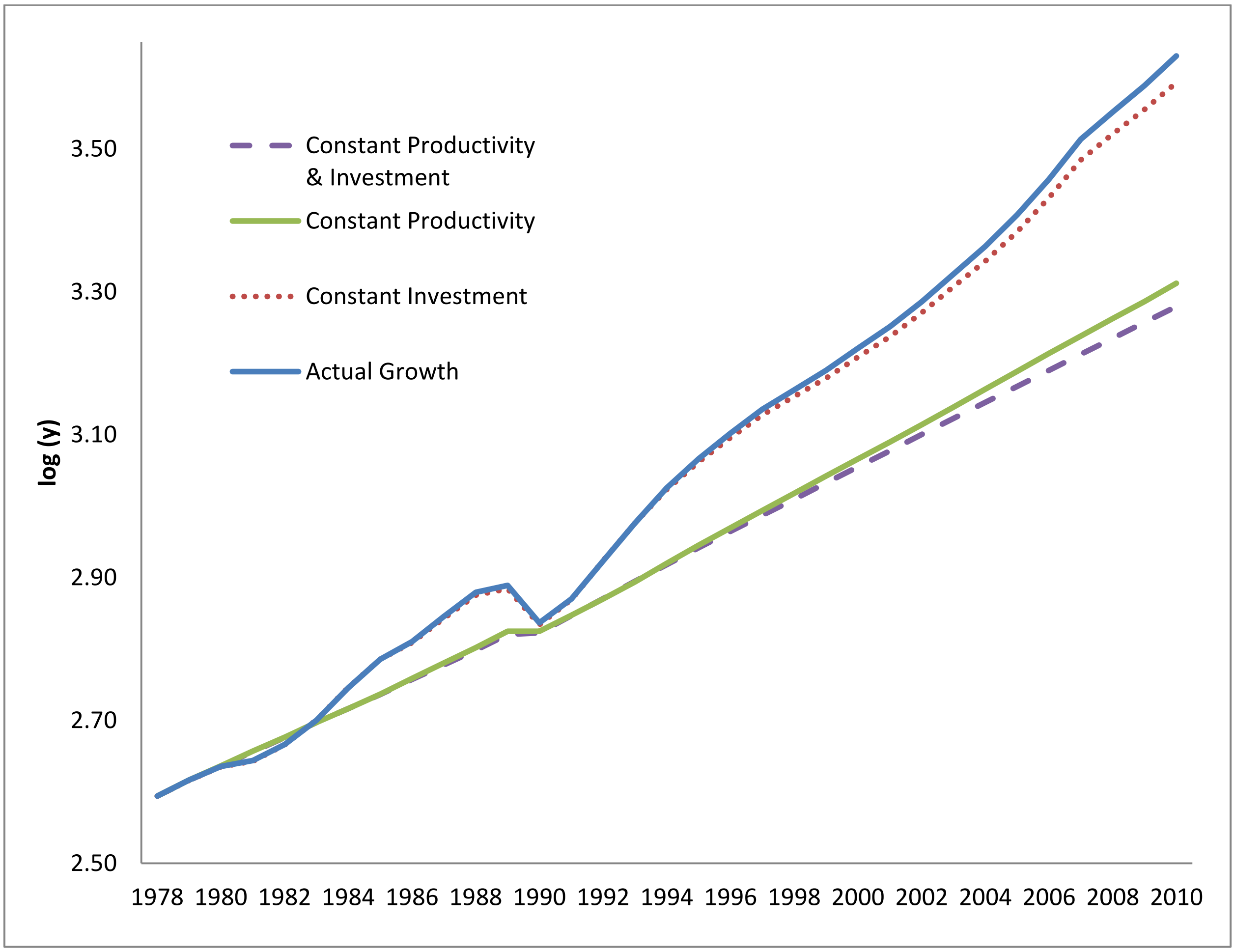


Table 3 contains a more detailed breakdown of the results described in Figure 3. Column 1 shows the ratio of output per worker from 2010 to the starting year in 1978, giving the factor by which output has grown over the 32 year span. Column 2 is the implied growth rate associated with this increase in output. Column 3 lists the additional growth that arises from the base series (1) where both productivity and investment growth are held constant, and column 4 shows the relative contribution each series had in increasing from the base (1) to the actual growth path. The results of this decomposition show that investment contributed approximately 9.2% to 10.7% of the rise in the growth rate of output per worker.

Table 3: Growth Simulation Results (α=1/3)

Counterfactual Growth and Relative Contribution of Investment and Productivity from 1978				
	y_{2010}/y_{1978}	Average Implied Growth Rate	Additional Growth from (1)	Relative Contribution
Constant productivity and investment (1)	4.84	5.22	--	--
Constant productivity, actual Investment (2)	5.22	5.48	0.26	9.19
Constant investment, real productivity (3)	9.97	7.70	2.48	89.30
Actual Growth	10.86	8.00	2.78	100.00

The results computed in Table 3 are sensitive to the value of α that is used. The conventional value of α = 1/3 is used in the calculations for Table 3. The same table is recreated in the Appendix using values of 0.3 and 0.4 for α. Lower values of α reduce the importance of the rising investment rate in explaining the increasing growth rate of output per worker. With the lower value of α = 0.3 investment rate changes explain only about 7.5% of the change in the rate of growth of output per worker. For the higher value of α = 0.4 this rises to approximately 14.5%. While the results are somewhat sensitive to the parameter values chosen, it remains reasonable to conclude that investment has played only a secondary role in explaining the increases in the growth rate of output per worker over the period.

Over this 32 year period the investment rate increased from just below 30% to a little over 40% or an increase in the investment rate by a factor of roughly 1/3. Meanwhile the productivity growth rate more than doubled as it rose steadily from about 3.15% to 6.56%. Because of this it is not surprising that the increase in productivity explains a much larger portion of the change in the rate of growth of output per worker.

Interestingly, when we examine the period after the reforms, beginning at 1994, the results are reversed, as seen in Figure 6. Over this period the investment rate increase explains a larger portion of the rate of growth of output per worker than the rising rate of productivity growth. The main reason for this reversal is that from 1994 to 2010 the investment rate increased by a factor of about 1/3, however the productivity growth rate increase was much less dramatic, increasing by about 1.25% or a factor of a little less than 1/4.

Figure 6 shows the result of this growth simulation from 1994 onward. Once again the base series holds both investment and productivity growth constant at 30.9% and 5.3% as mentioned earlier. There are then the two series where productivity growth and investment are held constant separately, allowing the other variable to follow the actual path from observed data. The remaining series is once again the actual growth path of output from 1994 to 2010.

Figure 6: Growth Simulations beginning in 1994

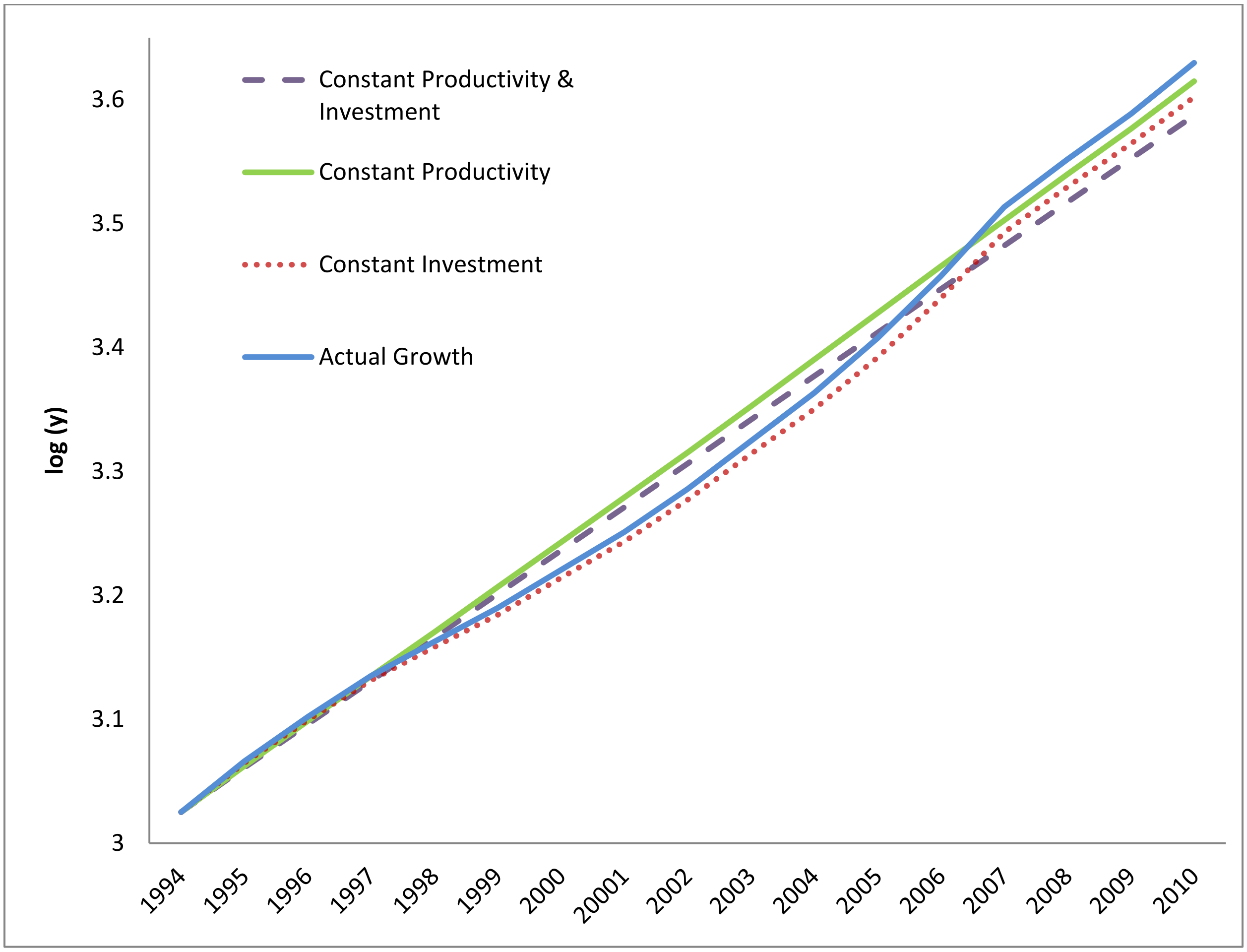


Table 4 breaks down the results for the simulations beginning in 1994. The columns are analogous to those from Table 3. Here nearly 2/3 of the rise in the output per worker growth rate can be attributed to the rising investment rate, compared with only 1/3 attributable to the rising productivity growth rate. Once again the results are sensitive to the parameter α. Table 4 is calculated using a value of α=1/3. When α=0.4 the amount attributed to the rising investment rate rises to over 80%, and when α=0.3 the amount attributed to the rising investment rate drops to about 55%. The tables for these alternate specifications of α are found in the Appendix.

Table 4: Growth Simulation Results (α=1/3)

Counterfactual Growth and Relative Contribution of Investment and Productivity from 1994				
	y_{2010}/y_{1994}	Average Implied Growth Rate	Additional Growth from (1)	Relative Contribution
Constant productivity and investment (1)	3.65	8.42	--	--
Constant productivity, actual Investment (2)	3.89	8.86	0.43	64.84
Constant investment, real productivity (3)	3.78	8.66	0.23	34.84
Actual Growth	4.02	9.09	0.67	100.00

7. Conclusion

Examining the counterfactual series reveals that the increase in the Chinese investment rate since 1978 made a relatively small contribution to the increase in the rate of growth of output per worker. In the absence of a rising investment rate the rise in the growth rate of output per worker over the period would have been lower by only about 10%. While this shows that the investment rate was clearly not the leading source of growth for the country, it has had a marginal impact. An increase in the investment rate from around 30% of GDP up to just over 40%, or an increase by a factor of a little over 1/3 led to a rise in the rate of growth of output per worker by about 10% more than what would have been experienced otherwise. When examining the changes over the more recent post reform period from 1994 to 2010 the role of investment has become more prominent. Over this period the increased investment rate can perhaps explain as much as 1/2 or more of the growth rate change, however this measure becomes quite sensitive to the value of capital's factor share. Also, while this shows that investment may have played a significant role in the change in growth rate, the nominal change was relatively small, meaning investment only explains a relatively small portion of overall growth.

A number of extensions remain for future work. The analysis in this paper uses a very simple Cobb-Douglas production function, using only capital, labour, and residual productivity. This framework could be extended to work with a more complex production function that includes other factors of production, such as human capital, land, or other technologies. The more complex production function would allow for a more thorough analysis of the contribution of these other factors along with a more accurate analysis of the contribution of the rising investment rate to Chinese economic growth. A more complex production function could also attempt to capture the change in the composition of the Chinese labour force. As noted by Chen (2010), China's labour force has undergone a dramatic change with millions of labourers shifting from the rural to urban sectors. This labour composition shift could be a key to explaining some of the rise in the rate of growth of output per worker, particularly through rises in productivity.

Another extension could try and capture a more accurate measure of capital depreciation. This paper uses a constant depreciation rate of 2.5%, which may not be the most appropriate method of capturing depreciation. Many of the databases that contain the measures of capital formation also have series identifying the capital lost to depreciation. The problem with using this series of capital depreciation arises when constructing the counterfactual series. If the counterfactual capital series remains too low, the amount of capital lost to depreciation becomes so great that it overshadows investment completely and can lead to a decreasing capital stock. A method would need to be established to try and capture a more accurate level of depreciation while avoiding this problem.

Appendix

Initial Capital Stock Calculation

Calculating the initial capital stock level is based on a commonly used method (see Nehru and Dhareshwar (1993)). Recall the capital accumulation equation is:

$$K_{t+1} = K_t + I_t - \delta K_t$$

Rearranging this equation we get:

$$\frac{K_{t+1} - K_t}{K_t} = \frac{I_t}{K_t} - \delta$$

The left hand side of the equation is the growth rate of capital. The method assumes that this growth rate is equal to the growth rate of output, denoted here as g. This assumption is based on the capital-output ratio remaining constant which implies that capital and output grow at the same rate. Substituting this in to the equation and rearranging gives us the equation to determine the level of the capital stock:

$$K_t = \frac{I_t}{(g + \delta)}$$

This now gives the capital stock in terms of investment, output growth, and depreciation for which we have observed values. In order to avoid short term variations in the measure of investment or output growth 3-year averages are used to calculate the starting level of capital stock.

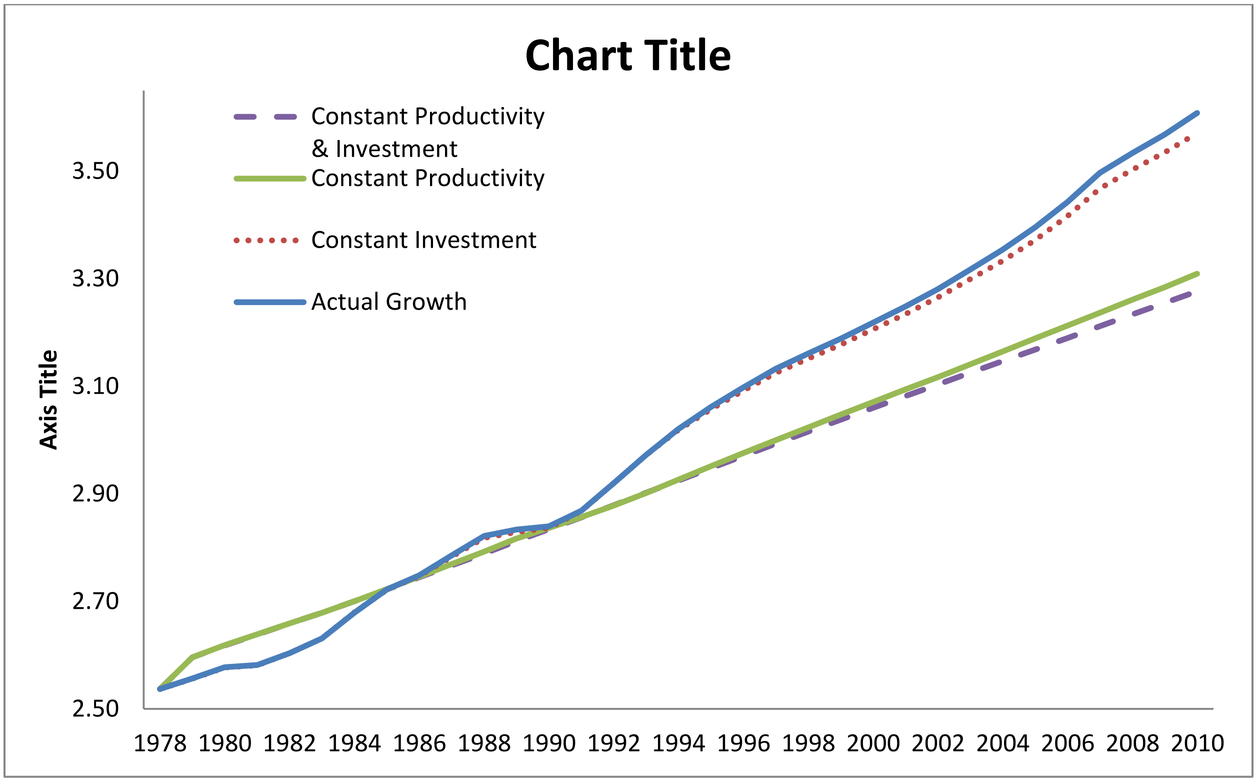
Artificial Labour Series

The labour force series has an abrupt change, rising by nearly 95 million workers in the year 1990. This rise is likely due to a change in the method or source of measurement used as opposed to an actual increase in the labour force. Because of this potential issue I create an artificial labour series based on population statistics. Data on the population is more readily available including data on the portion of the population that is of working age (15-64). Using the labour force data from 1990 onward and comparing this level to the working age population shows that the portion of working age population that is employed remains relatively constant at about 87-88%. This breaks down roughly to the equation:

$$Labour\ Force \approx (.88 - unemployment)\ x\ Working\ Age\ Population$$

Using this basic formula I extended the artificial labour series back further, holding the unemployment level roughly constant for the years over which there are no observations. Doing so gives a labour force series without a large discrete jump. Using this artificial labour series in the experiments proved to have very little effect on the results, so the paper contains just the results using the observed labour force data from the China Data Center. Figure 7 shows the growth simulations using the artificial labour series.

Figure 7: Growth simulations beginning in 1978 using Artificial Labour Series



<u>Hodrick-Prescott Filter</u>

A Hodrick-Prescott (HP) filter is used to smooth out many of the data series to get a better sense of the overall trend and remove any cyclical variation in the series (Wikipedia, 2012). The basic framework of the HP filter is based around the series being made up of a trend component (τ) and a cyclical component (c).

$$y_t = \tau_t + c_t$$

The cyclical component can then be solved by using the equation:

$$\frac{\min}{\tau}\{\sum_{t=1}^{T}(y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1}[(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2\}$$

The parameter λ is a positive constant which penalizes variability in the growth component of the equation. The value for λ used here is 100 which is the recommended value for yearly data.

Robustness using different values of α

Tables 5 through 8 contain alternate specifications of α for the growth simulation results.

Table 5: Growth Simulation Results (α=0.4)

Counterfactual Growth and Relative Contribution of Investment and Productivity from 1978				
	y_{2010}/y_{1978}	Average Implied Growth Rate	Additional Growth from (1)	Relative Contribution
Constant productivity and investment (1)	5.66	5.75	--	--
Constant productivity, actual Investment (2)	6.23	6.08	0.33	14.65
Constant investment, real productivity (3)	9.76	7.63	1.88	83.50
Actual Growth	10.86	8.00	2.25	100.00

Table 6: Growth Simulation Results (α=0.3)

Counterfactual Growth and Relative Contribution of Investment and Productivity from 1978				
	y_{2010}/y_{1978}	Average Implied Growth Rate	Additional Growth from (1)	Relative Contribution
Constant productivity and investment (1)	4.51	4.98	--	--
Constant productivity, actual Investment (2)	4.81	5.20	0.22	7.35
Constant investment, real productivity (3)	10.07	7.7345154	2.76	91.31
Actual Growth	10.86	8.00	3.02	100.00

Table 7: Growth Simulation Results (α=0.4)

Counterfactual Growth and Relative Contribution of Investment and Productivity from 1994				
	y_{2010}/y_{1994}	Average Implied Growth Rate	Additional Growth from (1)	Relative Contribution
Constant productivity and investment (1)	3.66	8.44	--	--
Constant productivity, actual Investment (2)	3.96	8.98	0.54	83.14
Constant investment, real productivity (3)	3.72	8.55	0.11	16.86
Actual Growth	4.02	9.09	0.65	100.00

Table 8: Growth Simulation Results (α=0.3)

Counterfactual Growth and Relative Contribution of Investment and Productivity from 1994				
	y_{2010}/y_{1994}	Average Implied Growth Rate	Additional Growth from (1)	Relative Contribution
Constant productivity and investment (1)	3.63	8.39	--	--
Constant productivity, actual Investment (2)	3.84	8.77	0.38	54.41
Constant investment, real productivity (3)	3.80	8.71	0.32	45.13
Actual Growth	4.02	9.09	0.70	100.00

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