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WIDER Working Paper 2020/155

Effects of productivity growth on domestic savings across countries

Disentangling the roles of trend and cycle

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November 2020

United Nations University World Institute for Development Economics Research
wider.unu.edu

Abstract: Resource mobilization continues to be an important policy challenge for developing economies, raising questions as to what determines differences in saving behaviour across countries. Using a panel of 47 economies with at least 40 years of continuous time series data, we causally identify, using a range of approaches, that higher productivity growth leads to greater savings, thereby contributing to higher investment. The dynamics of such productivity shocks have been disentangled into trend and cyclical shocks to uncover that cyclical productivity shocks tend to have a strong positive effect on saving rates. Comparing two countries with different levels of productivity (high and low) in a counterfactual analysis, this result remains robust, and we reconfirm that large declines in productivity shocks were associated with large decline in saving rates. Countries should focus on promoting policies to boost productivity growth and thereby achieve higher savings instead of focusing on savings-induced policies alone.

Key words: saving, productivity growth, trend shock, cyclical shock, causal identification

JEL classification: E21, E22, E32, E60

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This study has been prepared within the UNU-WIDER project The domestic savings shortfall in developing countries—what can be done about it? which is part of the Domestic Revenue Mobilization programme. The programme is financed through specific contributions by the Norwegian Agency for Development Cooperation (Norad).

Information and requests: publications@wider.unu.edu

ISSN 1798-7237 ISBN 978-92-9256-912-9

https://doi.org/10.35188/UNU-WIDER/2020/912-9

Typescript prepared by Gary Smith.

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The Institute is funded through income from an endowment fund with additional contributions to its work programme from Finland, Sweden, and the United Kingdom as well as earmarked contributions for specific projects from a variety of donors.

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1 Introduction

With the seminal work of Ramsey (1928) on the theory of savings, the concept of consumption smoothing emerged with the permanent-income hypothesis of Friedman (1957). Only a permanent shock to income should lead to significant change in consumption, whereas a positive transitory shock to income is more likely to be saved to smooth consumption. Another important theoretical contribution in the area of saving has been the life-cycle hypothesis of Modigliani (1970), emphasizing the role of demographic structure in savings. Modigliani (1970) showed, on the basis of a large cross-section of countries, that both the ratio of old-age population (aged 65 and over) and of young population (below 20) to the working-age population (20–65) had a strong and highly significant negative effect on the saving ratio. Carroll (1994) provided evidence that consumption does not respond to any predictable change in income, but that it responds to future income uncertainty, in line with the buffer stock model of saving. The buffer stock model of Carroll et al. (1992) and Carroll (1997) cast doubt on both life-cycle and permanent-income models.

The issue of saving has been very important in the development literature, as saving leads to investment, which increases capital stock and output. According to Lewis (1954), 'The central problem in the theory of economic development is to understand the process by which a community which was previously investing and saving 4 or 5 per cent of its national income or less, converts itself into an economy where voluntary saving is running at about 12 to 15 per cent of national income or more.' There is thus consensus about the benefits of higher saving ratios, but there is a lack of consensus on the mechanism to achieve this, which could be due to differences in belief and evidence about saving–growth causation.

Our paper is related to several strands of the literature on saving and consumption. The most important one is the causation between growth and saving. It was believed in the 1950s and 1960s that low saving rates in poor countries were the reason for lower economic growth in those countries, and the focus was to augment their saving ratios. One obvious way to augment the saving ratios in these countries was to provide external aid (Burnside and Dollar 2000, 2004). There are studies that suggest this aid rarely worked, and questions, which are still unresolved, were raised regarding this proposed causation (Easterly 2003; Easterly et al. 2003). Carroll and Weil (1994), using a purely data-driven approach, suggest that all significant increases in saving ratios across countries have been preceded by higher growth rates. For example, even after South Korea was growing rapidly, Williamson (1979) wrote an article questioning the lower saving rate in the country.[1] The period of high income growth in Japan began in the late 1940s and early 1950s, but particularly high saving rates were not established there until the 1960s and 1970s. Understanding the causation between saving and growth is important for policy-makers, as it can lead to prioritization of policies with the correct focus.

A second strand of the literature is the determination of cross-country variation in saving rates. Loayza et al. (1998) found that real interest rate, per capita income and its growth, ratio of money supply to gross national disposable income, old-age dependency ratio, young-age dependency ratio, terms of trade, inflation rate, and financial sector development are important determinants of saving. Aizenman and Noy (2013), on the other hand, cast doubt on the theory of precautionary savings in which income volatility should increase saving. They argue, supporting their theory with an overlapping generation model, that savings in Latin America are low, and more specifically are significantly lower than in East Asia, even though Latin America's macro economies are generally much more volatile. Contrary to this, Mody et al. (2012) use a panel of OECD countries and argue that at least two-fifths of the increase in households' saving rates between 2007 and 2009 were due to increased uncertainty about labour-income prospects. This suggests that temporary income shocks are equally important for higher savings.

[1] Korea as used in this paper refers to South Korea.

Fernandez et al. (2019), with a simple neoclassical model of growth with government consumption, population growth, TFP (total factor productivity) growth and capital taxation, determined a model-based saving rate and compared it with the observed savings rate. They find that their model-based saving rate and actual savings are similar in explaining saving. They suggest that feeding the TFP growth of East Asian economies into Latin American economies increases their savings by 5 per cent, but that is not enough to close the gap between saving rates in East Asia and Latin America. Therefore, they suggest that the lower saving rate in Latin America is not mainly due to low TFP growth in Latin America, but fiscal policy changes lowering tax rates are able to account for some of the major fluctuations in saving rates observed during this period. Also, smoothing of consumption requires that there is no credit friction, as better developed local financial markets can facilitate borrowing and hence lower savings. Also, foreign inflows (mainly foreign direct investment (FDI)) can offset domestic savings in financing investment projects in a country.

A third strand of the literature relates to the theoretical issues linking productivity shock, habit persistence in consumption, and saving ratio. The permanent-income hypothesis suggests that only permanent changes in income should lead to significant changes in consumption. Therefore, most of the cyclical variation in income should be saved. This implies that cyclical productivity shock should increase the saving ratio. Also, permanent productivity shock implies that income is going to be even higher than it is today and should increase current consumption and decrease the saving ratio. This means that the impact of the permanent component of productivity shock on the saving ratio crucially depends on the persistence of the permanent component of the shock, a point that is not well appreciated in the literature (Aguiar and Gopinath 2007). Thus, habit persistence also matters for the saving ratio in line with the arguments made by Carroll et al (2000).

In this paper we approach the issue of savings–growth causation via the savings rate and productivity growth. We also decompose productivity growth into permanent and transitory components. This relates our paper to a fourth strand of the literature, arguing for differences in volatility of the permanent component of productivity shocks in advanced and emerging economies (Aguiar and Gopinath 2007). Trend productivity shock should be the main source driving fluctuations in consumption, and if trend shocks turn out to be more volatile, then it can make consumption more volatile.

This paper contributes to all of the above strands of the literature. Using saving and growth transitions we show that increase in growth is followed by sustained increase in saving ratio, whereas the saving transitions are not followed by sustained increase in the growth rate. This provides the near-causal evidence in the paper suggesting that growth is followed by the saving ratio, not the other way around. The regression estimates give positive and significant effects of TFP growth on saving.

We find that the standard deviation of TFP growth is higher in non-high-income countries in comparison to high-income countries. Even our model-based shocks have this pattern, suggesting that productivity shocks have higher variance in non-high-income countries in comparison to high-income countries. Also, without habit persistence in consumption, we find that a large fraction of non-high-income countries is dominated by trend shocks in productivity, which substantiates the findings of Aguiar and Gopinath (2007) for a large set of countries. But with habit in consumption we find only two non-high-income countries are dominated by trend shocks, and none of the high-income countries are dominated by trend shocks. It seems to us that Aguiar and Gopinath (2007) claim that emerging economies are dominated by trend productivity shocks, which could be driven by their model specification and may not hold in general.

To eliminate the simultaneity and omitted variable bias, we estimate the productivity shock from a neoclassical growth model (real business cycle model) for 47 countries in our sample. We use this shock as a measure of productivity shock directly as well as an instrument for TFP growth in our regressions. Productivity shock has been widely used in macroeconomic research to understand the business cycle (see Basu and Fernald 2002; Basu et al. 2006; Gali 1999; Gali et al. 2000; Gortez et al. 2017). We also argue that model-based productivity shocks are exogenous and therefore should not lead to endogeneity in regression, and this allows us to do a causal estimation of the effects of productivity growth on savings. Use of model-based shocks for identification being done in this paper is very similar to the recent work by Barnichon and Mesters (2020).

Our model-based evidence from these regressions suggests that the cyclical productivity shock turns out to be significant in explaining cross-country variation in savings rate, whereas the permanent component of productivity shock does not turn out to be significant in a cross-country set-up. Also, we estimate model-generated savings by running a counterfactual analysis, comparing a high-TFP-growth country and a low-TFP-growth country. We show that large declines in productivity shocks were associated with large declines in savings rates. Therefore, countries should focus on promoting policies to boost productivity growth and thereby achieve higher savings instead of focusing on savings-induced policies alone.

The plan of the paper is as follows. Section 2 gives some stylized facts from data and causal evidence of growth on saving, using savings and growth transitions. Section 3 presents a tale of two countries, Korea and Cameroon. We use this to investigate the role played by productivity shocks in decreasing the saving ratio in Cameroon, a country that experienced a large drop in the saving ratio in a very small span of time. Section 4 explains the calculation of TFP growth from data and the model used to estimate productivity shocks. Section 5 briefly explains the data and the empirical framework, and presents the results, followed by a counterfactual analysis for Cameroon. Section 7 concludes and suggests policies resulting from the empirical evidence in this paper.

2 Some stylized facts

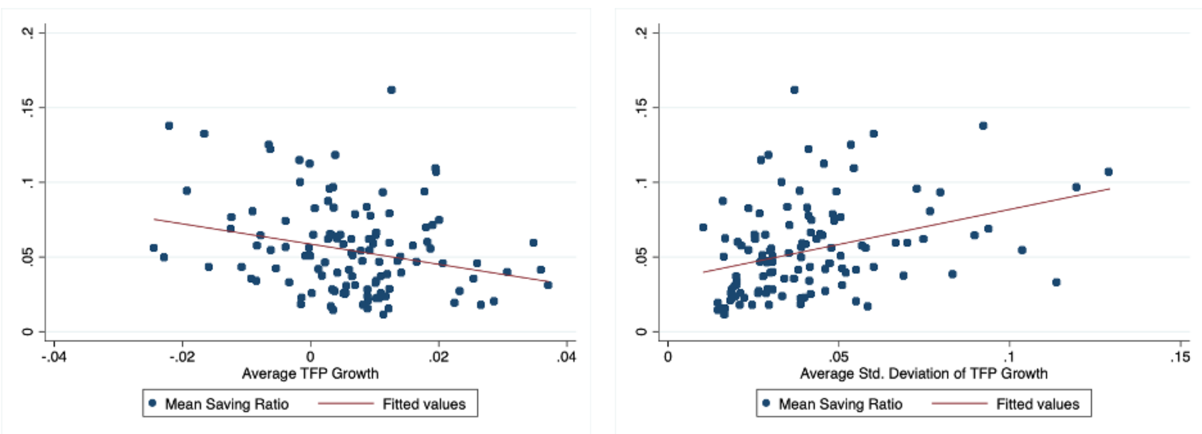
2.1 Saving and TFP growth

Figure 1(a) shows the relationship between the mean saving ratio and mean Hicks-neutral TFP growth in our sample. The relationship is negative, implying that countries with higher average TFP growth have lower saving. Figure 1(b) gives the relationship between the mean saving ratio and mean standard deviation of the Hicks-neutral TFP growth in our sample.

Figure 1: Saving and TFP across countries

(a) Average saving and average TFP growth

(b) Average saving and average standard deviation of TFP growth

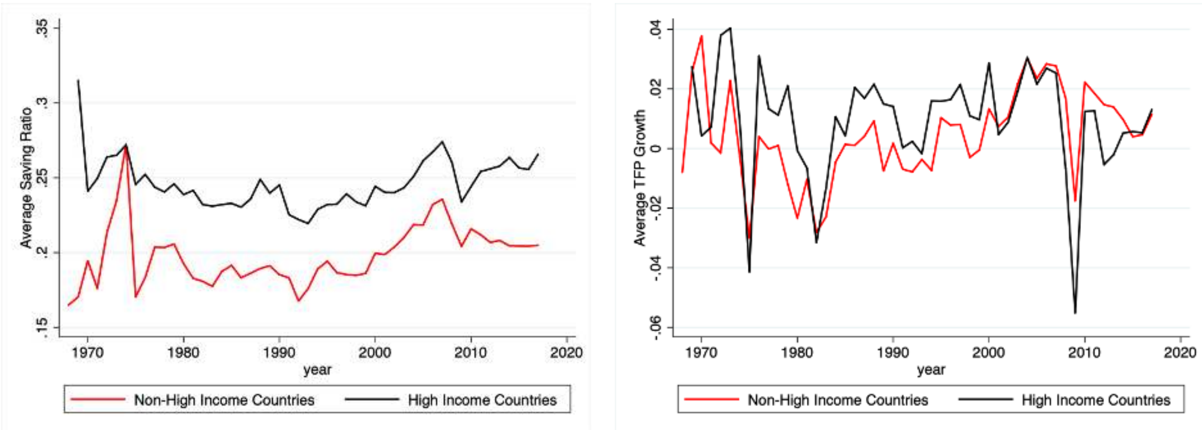


Source: authors' construction based on data from the World Bank.

The relationship is positive, implying that countries with higher average standard deviation of TFP growth have higher saving rates. Therefore, TFP growth affects saving in two different and opposite ways. It is possible that a country with low TFP growth may have higher saving because of higher volatility in the TFP growth. Figure 2(a) gives the mean saving ratio over years in our sample for high- and non-high-income countries. We use the World Bank classification to select high-income countries; the rest of the countries in our sample are categorized as non-high-income countries. As we can see, the average saving ratio is higher in high-income countries. Figure 2(b) gives mean TFP growth over time in our sample for high- and non-high-income countries. Average TFP growth is higher in high-income countries, and during economic downturns the fall in TFP growth is also higher for high-income countries.

Figure 2: Saving and TFP growth across high- and non-high-income countries

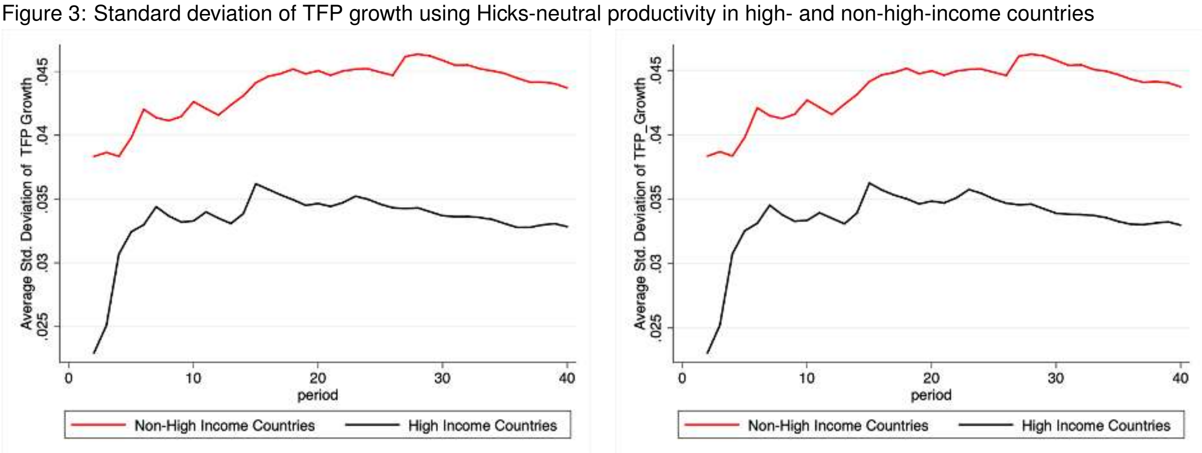
(a) Average saving (b) Average TFP growth



Source: authors' construction.

Figure 3 gives mean standard deviation of TFP growth over time in our sample by high- and non-high-income countries. With TFP growth and country classification, we construct the standard deviation of TFP growth on a recursive basis across these two sets of countries and then take the average. As we can see, the standard deviation of TFP growth is higher in non-high-income countries than high-income countries.

Figure 3: Standard deviation of TFP growth using Hicks-neutral productivity in high- and non-high-income countries



Note: the first column is for average years of schooling for the population aged 15+; the second column is for average years of schooling for the population aged 25+.

Source: authors' construction.

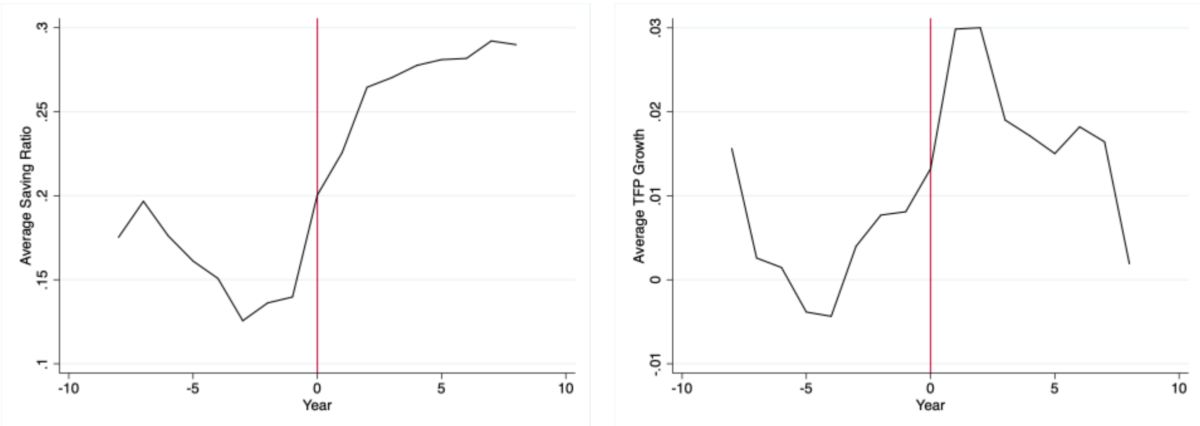
2.2 Saving and TFP transitions

In our sample we have many countries that experienced a significant change in saving ratio as well as TFP growth in a very short span of time. We use this to identify saving and growth transitions. Saving transition is defined as follows: at each point in time we calculate the three-year forward moving average of saving ratio (the current year and the two years after that) and the five-year backward moving average of saving ratio (the current year and the four years before that). A transition is said to have occurred in a year for a country if the difference between the forward moving average in a particular year and up to six years ahead and backward moving average one year before is larger than 5 per cent. We also impose the condition that the forward moving average in that particular year and up to six years ahead must be greater than 10 per cent.[2] Similarly, we define transition in TFP growth.[3]

For defining transition in TFP growth, we choose a smaller difference, as the growth rate in TFP is not likely to be big enough. Then we keep data for all countries before and after eight years of transition and calculate the mean for each year. Figure 4 gives the graph of the saving ratio and TFP during this time period for saving transitions. As we can see, saving transitions increase saving as expected, but it also increases TFP growth significantly. An important observation is that although these saving transitions make the saving ratio higher in the medium term, the growth in TFP is not sustained and tends to decrease.

Figure 4: Saving and TFP growth: transition based on the saving ratio

(a) Average saving (b) Average TFP growth



Source: authors' construction.

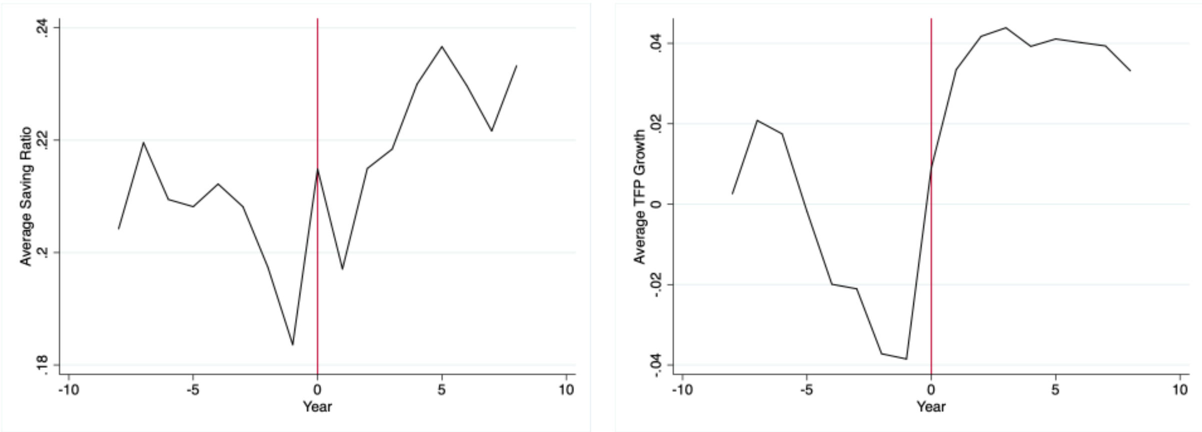
Figure 5 shows the graph of the saving ratio and TFP during this time period for growth transitions. As we can see, growth transitions increase growth as expected, but they also increase the saving ratio significantly. Now we see that a high saving ratio is sustained and growth remains higher. Therefore, it looks like causation goes from productivity growth to saving, not the other way around. A saving surge cannot keep growth higher, whereas a growth surge can keep saving higher, implying that it is the growth that is causing saving.

[2] Let s_1 and s_2 be the forward and backward moving average respectively as mentioned. Technically speaking, our transition condition is $s_1 > l.s_2 + 0.05$ and $f.s_1 > l.s_2 + 0.05$ and $f2.s_1 > l.s_2 + 0.05$ and $f3.s_1 > l.s_2 + 0.05$ and $f4.s_1 > l.s_2 + 0.05$ and $f5.s_1 > l.s_2 + 0.05$ and $f6.s_1 > l.s_2 + 0.05$ and $s_1 > 0.1$ and $f.s_1 > 0.1$ and $f2.s_1 > 0.1$ and $f3.s_1 > 0.1$ and $f4.s_1 > 0.1$ and $f5.s_1 > 0.1$, and $f6.s_1 > 0.1$.

[3] Let g_1 and g_2 be the forward and backward moving average respectively, as mentioned. Technically speaking, our transition condition is $g_1 > l.g_2 + 0.02$ and $f.g_1 > l.g_2 + 0.02$ and $f2.g_1 > l.g_2 + 0.02$ and $f3.g_1 > l.g_2 + 0.02$ and $f4.g_1 > l.g_2 + 0.02$ and $f5.g_1 > l.g_2 + 0.02$ and $f6.g_1 > l.g_2 + 0.02$ and $g_1 > 0.01$ and $f.g_1 > 0.01$ and $f2.g_1 > 0.01$ and $f3.g_1 > 0.01$ and $f4.g_1 > 0.01$ and $f5.g_1 > 0.01$, and $f6.g_1 > 0.01$.

Figure 5: Saving and TFP growth across countries based on TFP transitions

(a) Average saving (b) Average TFP growth



Source: authors' construction.

We use these windows around transition to estimate a regression of the saving ratio on growth. Table 1 gives the results from saving transitions. We have two measures of productivity growth, as explained in Section 4. As we can see, the productivity growth coefficient is statistically significant. The coefficient of productivity growth is higher if we estimate the regression with growth transitions, as we can see from Table 2. We can say that a 1 per cent increase in productivity increases the saving ratio by 0.2–0.3 per cent.

Table 1: Regression results: country–year based on saving transitions

	(1) Saving ratio	(2) Saving ratio
Hicks-neutral productivity growth	0.263***	
	(0.000)	
Harrod-neutral productivity growth		0.176***
		(0.000)
R^2	0.029	0.029
Observations	905	905

Note: *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Productivity growth has been obtained using baseline level accounting with average years of schooling for the population aged 15+. See Section 4 for details.

Source: authors' construction.

Table 2: Regression results: country–year based on TFP transitions

	(1) Saving ratio	(2) Saving ratio
Hicks-neutral productivity growth	0.308***	
	(0.000)	
Harrod-neutral productivity growth		0.207***
		(0.000)
R^2	0.083	0.083
Observations	781	781

Note: *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Productivity growth has been obtained using baseline level accounting with average years of schooling for the population aged 15+. See Section 4 for details

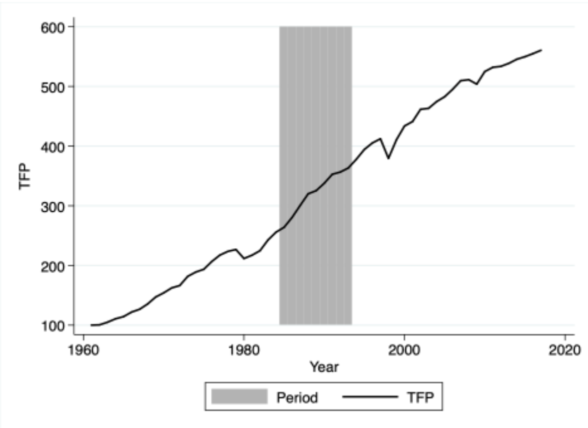
Source: authors' construction.

3 A tale of two countries: Korea and Cameroon

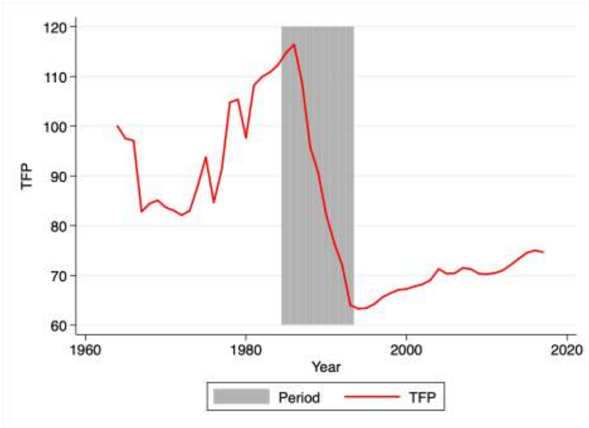
In this section we document the TFP, TFP growth, saving ratio, and investment ratio in Korea and Cameroon. There was a large fall in saving ratio in Cameroon during 1984–93. In the mid-1980s to late 1990s—as a result of international economic conditions, drought, falling petroleum prices, and years of corruption, mismanagement, and cronyism—Cameroon was hit by a serious economic crisis. The country turned to foreign aid, sharply cut government spending, and started privatizing industries to mobilize resources. Figure 6(b) shows the level of TFP for Cameroon. As we can see, there was a sharp decline in TFP in Cameroon. Figure 7(b) shows that TFP growth remained negative for the period 1984–93. Korea, on the other hand, remained on its steady-state path for TFP, as shown in Figure 6(a). The negative TFP growth in Cameroon was accompanied by a sharp fall in the saving ratio (Figure 6(c)).The growth model used in later sections to explore the impact of productivity growth on saving is a closed economy model. We adjust government expenditure with exports and imports. Therefore, in our model, saving is equal to investment. As we can see from Figure 8(b), there was a sharp fall in the investment ratio in Cameroon in the same period. This implies that saving and investment are closely related, and that our results obtained for saving are likely to hold for investment too.

Figure 6: TFP and savings in Korea and Cameroon

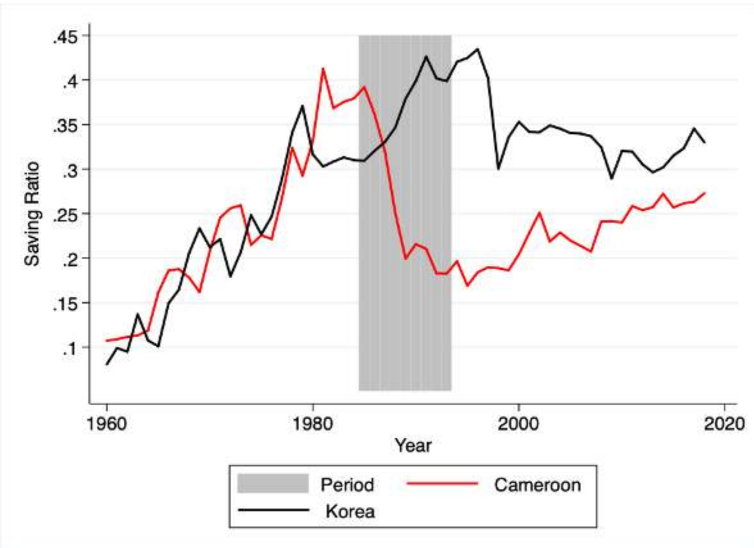
(a) TFP in Korea



(b) TFP in Cameroon



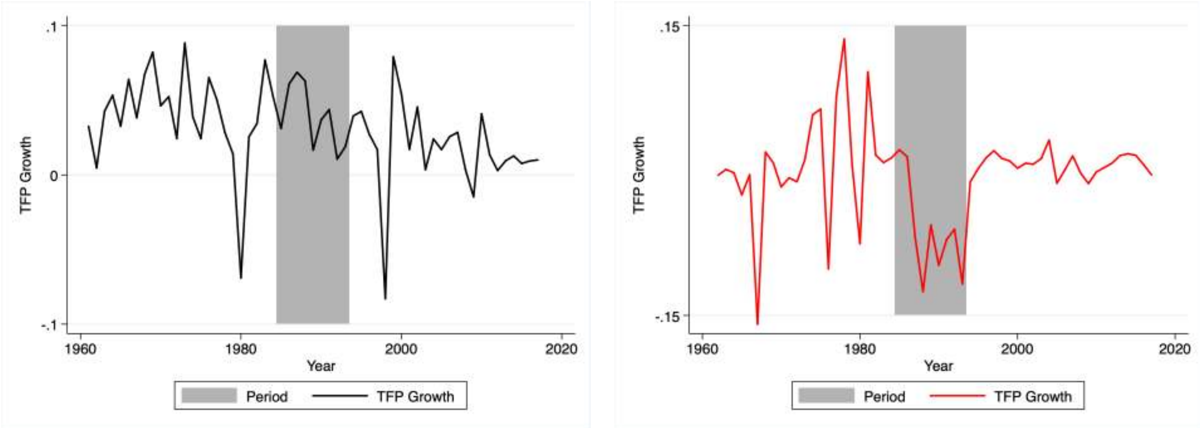
(c) Saving–investment ratio



Source: authors' construction.

Figure 7: TFP growth in Korea and Cameroon using Hicks-neutral productivity and average years of schooling for 15+ using baseline-level accounting

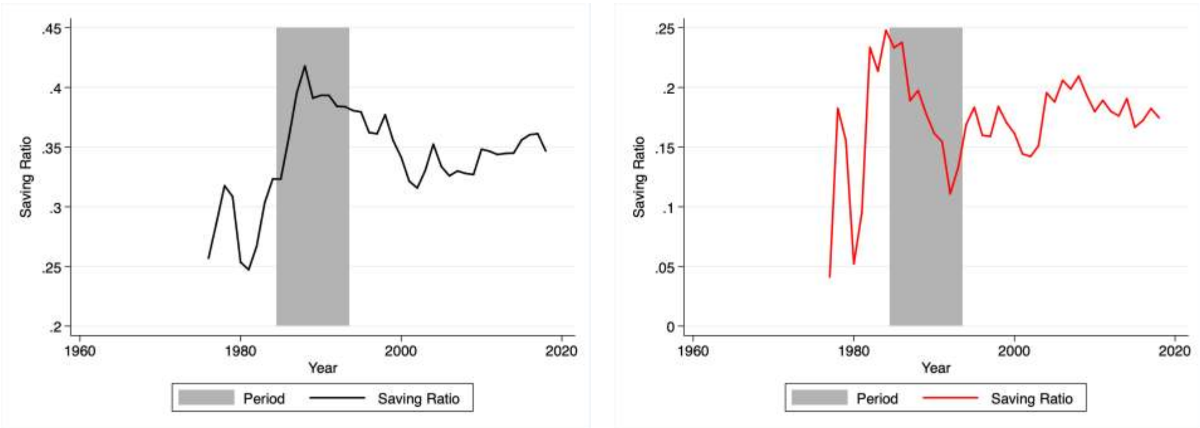
(a) TFP growth in Korea (b) TFP growth in Cameroon



Source: authors' construction.

Figure 8: Gross saving ratios in Korea and Cameroon

(a) Korea (b) Cameroon



Source: authors' construction.

Feldstein and Horioka (1979) give evidence that saving and investment are very tightly linked, and despite capital flows, investment is mostly explained by domestic saving.

4 Estimation of TFP

4.1 TFP from the data

Baseline decomposition

The basic Solow model is given by:

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

where L_t is the number of employed, K_t is capital stock, and h_t is average years of schooling. Productivity is assumed to be Hicks-neutral. Dividing by L_t, we get

$$y_t = A_t k_t^{\alpha} h_t^{1-\alpha}$$

where y_t and k_t are output and capital per worker. Capital is obtained from the Penn World Table (PWT). For h we use two data sets, those of Barro-Lee and UNESCO.[4] The Barro-Lee data set is till 2010, observed at five-year intervals beginning in 1960. We interpolate this data to obtain values in between. The UNESCO data is more up-to-date, but we interpolated any missing values. The major difference that we have is that the UNESCO data is for the population aged 25+, while the Barro-Lee data set is for the population aged 15+. We extrapolate these two data sets for missing values, and if the extrapolation results in negative values for years of schooling we replace it as missing. Years of schooling changes slowly and should not lead to any issues. The PWT also reports a measure of human capital. The two measures of human capital used here have very high correlation with the reported one (more than 0.9).

Correction for female labour force participation

Female education is improving in many countries, but at the same time female labour force participation has either stagnated or is decreasing. There is a possibility that gains made in education may not translate into gains in productivity. In other words, the variation in average years of schooling does not capture the variation in average years of schooling for the labour force. We calculate participation-based human capital using data from the World Bank. The Barro-Lee data set contains average years of schooling for the 15+ population and the 15+ female population. Using the expression below, we calculate average years of schooling for 15+ males:

$$\text{Average years of schooling}_{15+} = \frac{\text{Male population}_{15+} \times \text{Male average + Female population}_{15+} \times \text{Female average}}{\text{Male population}_{15+} + \text{Female population}_{15+}}$$

Once we have average years of schooling for 15+ males, we calculate the average years of schooling for those participating in the labour market using the expression below:

$$\text{Average years of schooling}_{\text{LF}} = \frac{\text{Male labour}_{15+} \times \text{Male average + Female labour}_{15+} \times \text{Female average}}{\text{Male population}_{15+} + \text{Female population}_{15+}}$$

Thus, we have three measures of average years of schooling: (1) average years of schooling from Barro-Lee; (2) average years of schooling from UNESCO; and (3) average years of schooling from Barro-Lee corrected for female labour force participation. Average years of schooling and human capital are related through:

$$h = e^{\varphi(s)}$$

where s is the average years of schooling. We assume $\varphi(s)$ to be piecewise linear as in Hall and Jones (1999). The slope of $\varphi(s)$ is 0.13 for $s \leq 4$, 0.10 for $4 < s \leq 8$, and 0.07 for $s > 8$. Therefore, we obtain three measures of human capital and therefore three measures of TFP. In $y_t = A_t k_t^{\alpha} h_t^{1-\alpha}$, we observe y_t, k_t, and h_t. We fix $\alpha = 1/3$ and obtain the value of A_t. This is our first decomposition that gives three measures of TFP. In the next subsection there is an alternative decomposition based on Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999), and we obtain three additional measures of TFP.

Alternative decomposition

From Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999),

$$Y_t = A_t K_t^{\alpha} (L_t h_t)^{1-\alpha} \implies \frac{Y_t}{L_t} = A_t \left(\frac{K_t}{L_t}\right)^{\alpha} h_t^{1-\alpha} \implies$$

Dividing and multiplying by y_t^{α},

$$1 = \frac{A_t (k_t)^{\alpha} h_t^{1-\alpha}}{y_t y_t^{\alpha}} y_t^{\alpha} \implies 1 = A_t \left(\frac{k_t}{y_t}\right)^{\alpha} h_t^{1-\alpha} y_t^{\alpha-1}$$

[4] http://www.barrolee.com and http://uis.unesco.org/en/topic/educational-attainment, respectively.

Therefore, we have

$$y_t^{1-\alpha} = A_t \left(\frac{K_t}{Y_t}\right)^{\alpha} h_t^{1-\alpha} \implies y_t = A_t \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} h$$

Knowing Y_t, K_t, and h_t, we can obtain estimates of A_t. Thus we obtain six estimates of TFP from the data. These are estimates of Hicks-neutral productivity. We repeat the same exercises with a Harrod-neutral productivity process given by

$$y_t = k_t^{\alpha}(A_t h_t)^{1-\alpha}$$

and obtain six measures of Harrod-neutral productivity. Once we have these measures of productivity, we estimate their growth rate.

4.2 TFP from the model

In this section we use a neoclassical growth model to understand the impact of productivity shocks on saving. This is important as this gives a benchmark to evaluate our empirical exercises. In addition to using TFP from the data, we estimate these models for countries in our sample and obtain the model-based productivity. We use these productivity shocks in our regression. We also use this productivity shock as an instrument for our TFP obtained from the data in the regression. We follow Chari et al. (2007) and augment the model with various features one by one.

Baseline

We start with the simplest neoclassical growth model. The representative household maximizes utility given by

$$U(c_t, n_t) = \log(c_t) + \chi \log(1 - n_t)$$

Their budget constraint is given by

$$c_t + (1 + \tau_{i,t})I_t = w_t n_t + r_t k_{t-1} + T_t$$

where $(1 + \tau_{i,t})$ is the investment wedge as in Chari et al. (2007). $\tau_{i,t}$ is the stationary zero mean process given by:

$$\tau_{i,t} = \rho_i \tau_{i,t-1} + \varepsilon_{i,t}$$

There is a growing literature that suggests that investment-specific technological change plays an important role in business cycles (Greenwood et al. 1997). Investment-specific technological shock influences relative price of investment and therefore affects investment. Our model is parsimonious, with few frictions, but Brinca et al. (2016) show that the investment-specific technology shock maps into our economy with investment wedges. Financial frictions are also important for investment and the financial frictions studied in Kiyotaki and Moore (1997) and Gertler and Kiyotaki (2009) also map investment wedges. Therefore, we are not modelling investment-specific technology shocks and financial friction explicitly, but our investment wedge should capture them. A household accumulates capital and the law of motion for this is given by:

$$k_t = (1 - \delta)k_{t-1} + I_t$$

The representative firm uses labour and capital to produce output using the Cobb–Douglas production function, which is given by:

$$y_t = A_t^{1-\alpha} k_{t-1}^{\alpha} n_t^{1-\alpha}$$

$$\log(A_t) = \rho \log(A_{t-1}) + \varepsilon_{A,t}$$

Here, we assume Harrod-neutral technological progress for reasons to be explained in the next section. There is government expenditure that fluctuates around a steady-state level of government-expenditure–output ratio:

$$G_t = (1 - \frac{1}{g_t})y_t$$

$$g_t = (1 - \rho_g)\log(g) + \rho_g \log(g_{t-1}) + \varepsilon_{g,t}$$

Trend growth in the stationary state

Expected higher growth in future income should increase consumption and decrease saving. Shock to growth is different from cyclical shock, as a shock to the growth rate implies a boost to current output, but an even larger boost to future output implies that consumption responds more than income, reducing savings and generating a current-account deficit (Stock and Watson 2003, 2005). Aguiar and Gopinath (2007) argue that the emerging economies are likely to have dominance of growth shocks over cyclical shocks. The impact of growth shocks on saving depends on the persistence of the shock. If the shock is not persistent, then saving increases instead of decreasing and will overturn the arguments made by Aguiar and Gopinath (2007). Higher persistence of growth shocks can induce a counter-cyclical current-account balance. Our production function is given by

$$y_t = A_t^{1-\alpha} k_{t-1}^{\alpha} n_t^{1-\alpha}$$

Taking log in both sides,

$$\log(y_t) = (1-\alpha)\log(A_t) + \alpha\log(k_t) + (1-\alpha)\log(n_t)$$

Differentiating with time and observing that there is no growth of labour hours, and on the balanced growth path, capital and output grow at the same rate, we can write:

$$g_y = (1-\alpha)g_a + \alpha g_y \implies g_y = g_a$$

This implies that the effective trend in the model is given by A_t where $\frac{A_t}{A_{t-1}} = z_t$. z_t is the growth rate and the economy achieves a steady-state growth rate given by $g_a = g_y$. The steady-state growth rate is obtained from data for each country in our sample:

$$\log(A_t) = \log(z_t) + \log(A_{t-1})$$

$$\log(z_t) = (1-\rho_z)\log(g_y) + \log(z_{t-1}) + \varepsilon_{z,t}$$

If we write the production function as Hicks-neutral, as

$$y_t = A_t k_{t-1}^{\alpha} n_t^{1-\alpha}$$

differentiating with time and observing that there is no growth of labour hours, and on the balanced growth path capital and output grow at the same rate, we can write:

$$\log(y_t) = \log(A_t) + \alpha\log(k_t) + (1-\alpha)\log(n_t)$$

$$g_y = g_a + \alpha g_y \implies g_y = \frac{g_a}{1-\alpha}$$

The effective trend is given by $A_t^{\frac{1}{1-\alpha}}$. Trend growth rate is given by $\frac{A_t^{\frac{1}{1-\alpha}}}{A_{t-1}^{\frac{1}{1-\alpha}}} = z_t$.

Assuming trend and cycle in productivity growth

The production function is given by:

$$y_t = A_t^{1-\alpha} k_{t-1}^{\alpha} n_t^{1-\alpha}$$

Technological progress is made up of two components:

$$\log(A_t) = \log(A_t^t) + \log(A_t^c)$$

The trend shock (having unit root) follows the process given below:

$$\log\left(\frac{A_t^t}{A_{t-1}^t}\right) = \log(z_t)$$

The effective trend is given by A_t^t and the growth of the trend is given by $\frac{A_t^t}{A_{t-1}^t} = z_t$. Where

$$\log(z_t) = (1-\rho_z)\log(g_y) + \rho_z(z_{t-1}) + {}_{z,t}$$

The cycle component of technology (stationary) process is given by:

$$\log(A_t^c) = \rho_{ac}\log(A_{t-1}^c) + {}_{ac,t}$$

Writing in terms of growth rates (taking the log and differentiating with respect to time) gives us:

$$\log(y_t) = (1-\alpha)\log(A_t) + \alpha\log(k_t) + (1-\alpha)\log(n_t)$$

$$\log(y_t) = (1-\alpha)\left[\log(A_t^t) + \log(A_t^c)\right] + \alpha\log(k_t) + (1-\alpha)\log(n_t)$$

Differentiating with time and observing that there is no growth of labour hours and on the balance growth path capital and output grows at the same rate, we can write:

$$g_y = (1-\alpha)g_a + \alpha g_y \implies g_y = g_a$$

Assuming trend and cycle in productivity growth and habit persistence

The household problem is given by:

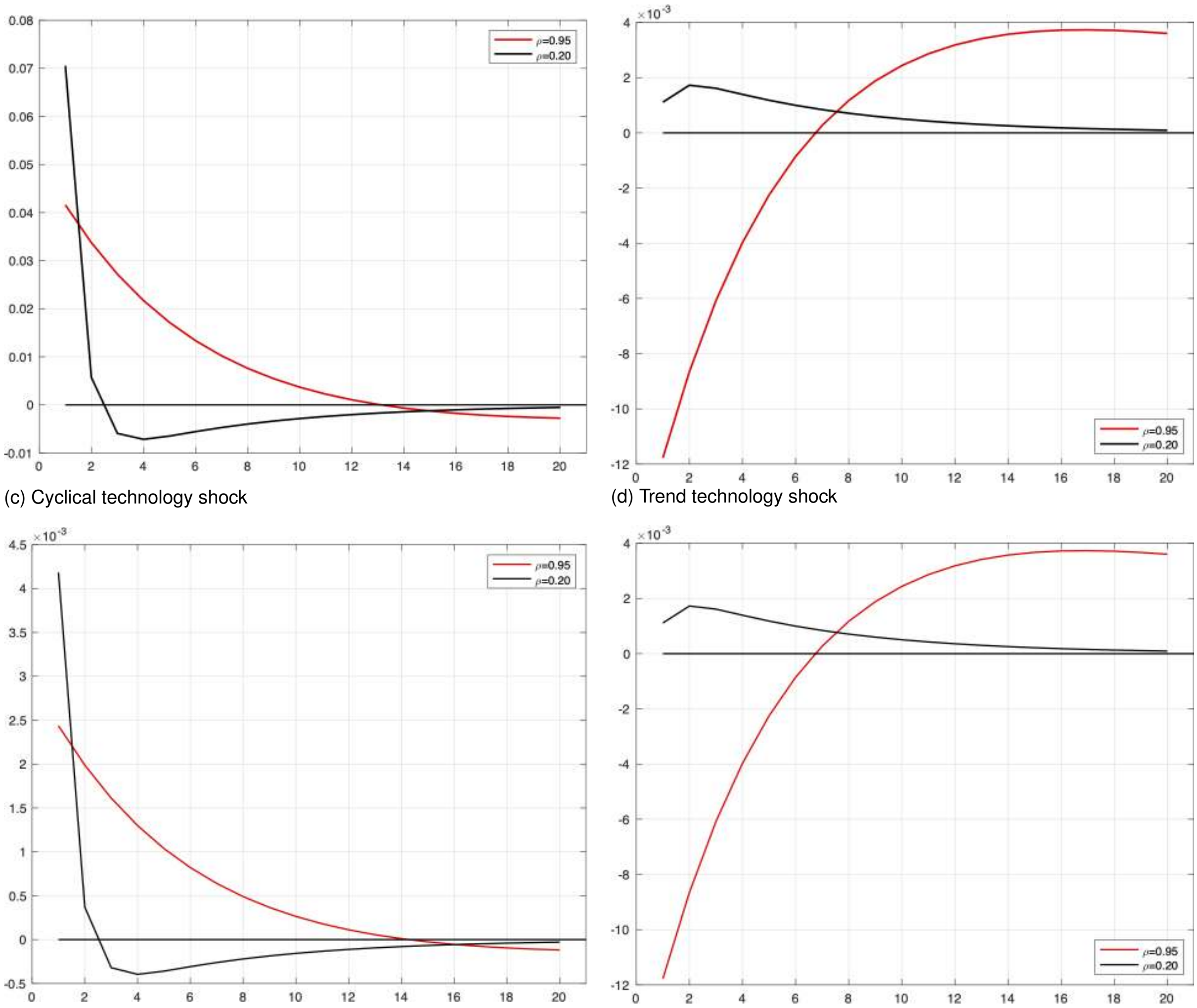
$$U(c_t, n_t) = \log(c_t - \gamma c_{t-1}) + \chi\log(1-n_t)$$

One can write $c_t - \gamma c_{t-1}$ as $c_t - \gamma c_t + \gamma c_t - \gamma c_{t-1}$. From there we can write $c_t(1-\gamma) + \gamma(c_t - c_{t-1})$. Higher values of γ imply that consumers attach more weight to growth of consumption in utility. The rest of the model, including technology shocks, remains the same as above. We solve these models and obtain the saving response, which is the same as investment from these models.

Prediction from the model

Figure 9(a) suggests that cyclical shock has an unambiguous effect on saving at impact. It increases saving on impact with high as well as low persistence. Figure 9(b) suggests that trend shocks decrease saving on impact if the trend shock is persistent, but increase saving if it is not persistent enough. This is the short-run impact of trend productivity shock on saving. In the long run, a trend productivity shock affects consumption and saving one to one as they share a common trend.

Figure 9: Response of saving ratio due to technology shock



(a) Cyclical technology shock

(b) Trend technology shock

(c) Cyclical technology shock

(d) Trend technology shock

Note: the second row gives the response from the model having both cycle and trend shocks.

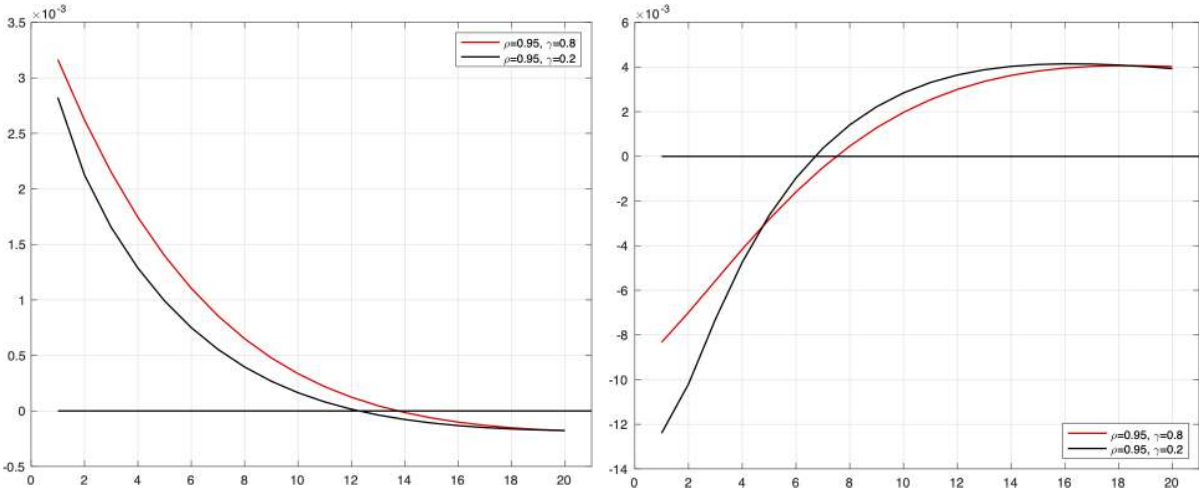
Source: authors' construction.

This brings additional challenges in estimating the impact of trend productivity shocks on saving. Only identifying the trend productivity shock is not sufficient; one needs to control for the persistence of the trend productivity shock. Figures 9(c) and 9(d) show the effect of cycle and trend shocks on saving from a model having both cyclical and trend productivity shocks. The impact is similar to the model having only cycle and only trend shocks. Figures 10(a) and 10(b) give the impact of a productivity shock on saving in the presence of habit persistence. Habit persistence significantly influences the impact of the productivity shock—both cyclical and trend—on saving. The intuition is simple; with habit persistence in consumption, even if one experiences a trend productivity shock, the consumption will not rise as much as it would have without habit; the same is true for a cyclical productivity shock. This is because habit persistence implies that the utility also comes from growth of consumption and higher consumption in the current period is likely to make consumption growth in the next period lower. Therefore, with habit persistence the cyclical shock leads to higher saving and the trend shock leads to lower dis-saving.

It is clear from the above discussion that cyclical shock has an unambiguous positive effect on saving, whereas the effect of trend productivity shocks on saving depends on the persistence of the trend productivity shock as well as habit persistence. The effect of cyclical shock also depends on habit, but the direction of the effect is unambiguous.

Figure 10: Response of saving ratio due to technology shock

(a) Cyclical technology shock (b) Trend technology shock



Note: Parts (a) and (b) give response from the model with both cycle and trend shocks for different values of habit persistence in consumption.

Source: authors' construction.

The Euler equation with cyclical productivity shock is

$$MU(c_t)\psi_{i,t} = \beta MU(c_{t+1})\left(\psi_{i,t+1}(1-\delta) + r_{t+1}\right)$$

The Euler equation with trend productivity shock is

$$MU(\tilde{c}_t)\psi_{i,t} = \frac{\beta MU(\tilde{c}_{t+1})}{z_{t+1}}\left(\psi_{i,t+1}(1-\delta) + r_{t+1}\right)$$

The main difference in the current-period saving due to cyclical and trend shocks arises due to differences in the Euler equation in our model. In the case of cyclical shock, the Euler equation does not depend on the technological progress. Since the income shock is transitory, a part of that would be saved for smoothing of consumption. But with the trend shock, the Euler equation does depend on the trend growth rate. In the extreme case, if the trend growth is not persistent, then with a shock to z_t the economy reaches a steady state in the next period and thus the effect of this shock should be similar to cyclical shock in our model. But if the trend growth has some persistence, then z_{t+1} is above the steady-state value and therefore the utility of transferring consumption in the next period is lower. Thus, current consumption increases and saving falls.

A shock to investment wedge $\psi_{i,t}$ is persistent, but the AR(1) coefficient is likely to be less than 1. Therefore, when a shock to investment wedge occurs, the left-hand side becomes greater than the right-hand side at the same interest rate because $\psi_{i,t} > \psi_{i,t+1}$, and this is the reason why the investment wedge reduces investment/saving and increases current consumption.

5 Data, empirical framework, and results

5.1 Data

Our main source of data is the World Bank and Penn World Table. We use general government final consumption expenditure, household final consumption expenditure, exports of goods and services, imports of goods and services, total population, and GDP per capita from the World Bank data set to estimate the model. First, following Chari et al. (2007), we calculate adjusted government expenditure by adding exports and subtracting imports from government expenditure. We drop all those countries that have negative value of adjusted government expenditure in our sample. These are likely to be countries with heavy import dependence. We keep countries with at least 40 years of observations. All variables are transformed in per capita terms. We construct TFP from data as mentioned earlier. We use three measures of human capital: (1) mean years of schooling (ISCED 1 or higher) of population aged 25+, obtained from the UNESCO data set; (2) mean years of schooling of population aged 15+, obtained from the Barro-Lee data set; and (3) We also construct a measure of human capital after correcting for labour force participation. Average years of schooling of women have increased across the globe, but their labour force participation has fallen. This means that the average years of schooling are biased in capturing the average years of schooling of the labour force. We use mean years of schooling of females aged 15+ obtained from the Barro-Lee data set, and female population aged 65 and above, male population aged 65 and above, total population aged 65 and above, female population aged 15–64, male population aged 15–64, total population aged 15–64, labour force, females as percentage of labour force, labour force participation rate for females, males, and total population, and real per capita GDP from the World Bank. Capital is obtained from the Penn World Table and transformed into per capita terms. The baseline panel regression contains GDP per capita, real interest rate (percentage), gross savings (percentage of GDP), old dependency ratio, young dependency ratio, broad money (percentage of GDP), domestic credit to private sector (percentage of GDP), trade (percentage of GDP), real effective exchange rate index (2010 = 100), net barter terms of trade index (2000 = 100), FDI, and net inflows (percentage of GDP), which are obtained from the World Bank. Per capita GDP, export, import, private consumption, government consumption, and capital are at constant prices in the local currency unit.

5.2 Empirical framework

Our baseline model is given by:

$$S_{it} = \varphi_i + \beta_1 YPC_{it} + Z_{it}\theta' + \varepsilon_{it} \tag{1}$$

where S_{it} is the saving–GDP ratio in country i in year t. YPC_{it} is the log of per capita income. Z_{it} are a set of controls (old dependency ratio, young dependency ratio, term of trade, broad money–GDP ratio, trade–GDP ratio, domestic private credit–GDP ratio, terms of trade, and real effective exchange rate). φ_i is country fixed effects. β_i gives the percentage change in saving to GDP ratio for one unit change in per capita income.[5] The non-linear impact of income on saving can be obtained by estimating the model given below:

$$S_{it} = \varphi_i + \beta_1 YPC_{it} + \beta_2 YPC_{it}^2 + Z_{it}\theta' + \varepsilon_{it} \tag{2}$$

The marginal effect with respect to per capita income is given by:

$$\frac{\partial S_{it}}{\partial YPC_{it}} = \beta_1 + 2\beta_2 YPC_{it}$$

The marginal effect of change in income on saving depends on the level of income. In other words, a US$1 change in income at a low level of per capita income and the same at a high per capita income lead

[5] Consider the model with the log to derive marginal effect:

$$S_{it} = \varphi_i + \beta_1 \log(YPC_{it})$$

$$\frac{\partial S_{it}}{\partial YPC_{it}} = \frac{\beta_1}{YPC_{it}} \implies \frac{\partial S_{it}}{\frac{\partial YPC_{it}}{YPC_{it}}} = \beta_1$$

to very different saving responses. The baseline model is augmented with TFP growth obtained from the data; it becomes

$$S_{it} = \varphi_i + \beta_0 TFP_{it} + \beta_1 YPC_{it} + \beta_2 YPC_{it}^2 + Z_{it}\theta' + \varepsilon_{it} \tag{3}$$

We first estimate Equation 2 and then Equation 3. Then we bring in the model-based TFP shocks in Equation 3, one by one. Finally, we estimate Equation 2 in which we use the model-based productivity shocks as an instrument for TFP growth.

5.3 Results

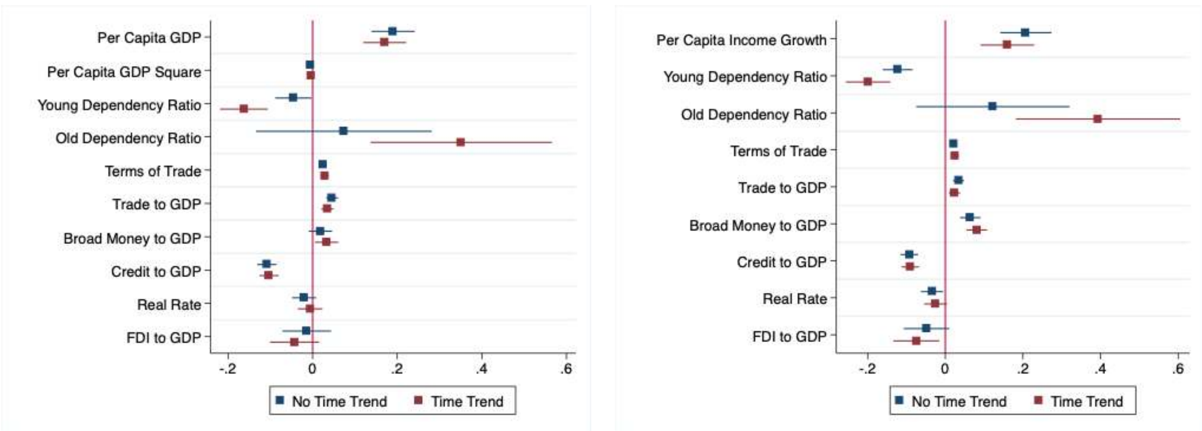
Baseline

The baseline regression result is given in Figure 11. Figure 11(a) is with per capita income and square of per capita income. Higher per capita income in our sample is associated with higher per capita saving and it is statistically significant. Per capita income squared turns out to be negative and significant, implying that at a threshold level of income, the relation between per capita income and saving ratio changes. Beyond the threshold level of income, the increase in per capita income leads to a decline in saving ratio. This could be partly due to the fact that high-income countries in our sample have lower saving ratios. The young dependency ratio turns out to be negative and significant, and the old dependency ratio is positive but significant only if we include the trend in the regression. Appreciation in terms of trade increases saving, a higher share of trade in GDP is associated with a higher saving ratio, and greater circulation of money also leads to a higher saving ratio. The credit to GDP ratio is likely to capture the extent of financial development, and a higher value of credit to GDP is found to be associated with a lower saving ratio. Surprisingly, we find that a higher real rate is associated with lower saving but the effect is not significant. Higher FDI leads to a lower saving ratio. This could be due to the fact that higher FDI implies lower requirements for domestic resources. We note that these coefficients are not causal; our focus is on productivity, to which we turn next.

Figure 11: Baseline regression estimates using determinants of saving based on the literature

(a) Estimates with per capita income

(b) Estimates with per capita income growth



Source: authors' construction.

Results from TFP in the data

We have six measures of Hicks-neutral TFP. The first is based on baseline-level accounting using average years of schooling for the population aged 15+. The second is based on baseline-level accounting using average years of schooling for the population aged 25+. The third is based on baseline-level accounting using average years of schooling for the population aged 15+, corrected for labour force participation as explained in the previous section. These three measures of human capital are used to obtain three more measures of TFP using level accounting based on Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999). We obtain six measures of Harrod-neutral productivity in a similar fashion.

The results for Hicks-neutral productivity growth are given in Table 3. Per capita income is positive and per capita income squared is negative, as before. The young dependency ratio is negative but not significant, and the old dependency ratio is negative and significant. Higher old dependency implies that there is a high number of people dis-saving. Terms of trade, trade in GDP, and money supply are positive as before and significant. Credit to GDP and FDI to GDP are negative as before and significant. The real rate is negative but not significant. Our coefficient of interest is the measures of TFP growth. The coefficient is positive and significant. The coefficient lies between 0.07 and 0.13. This implies that 1 per cent growth in TFP increases the saving ratio by 0.07–0.13 per cent on impact.

Table 3: Regression results from Hicks-neutral productivity

	(1) Saving ratio	(2) Saving ratio	(3) Saving ratio	(4) Saving ratio	(5) Saving ratio	(6) Saving ratio
Per capita GDP	0.118***	0.118***	0.116***	0.118***	0.118***	0.116***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Per capita GDP square	–0.00196*	–0.00200*	–0.00191	–0.00196*	–0.00200*	–0.00191
	(0.092)	(0.087)	(0.101)	(0.092)	(0.086)	(0.101)
TFP growth 1	0.125***					
	(0.001)					
TFP growth 2		0.100***				
		(0.005)				
TFP growth 3			0.124***			
			(0.001)			
TFP growth 4				0.0862***		
				(0.001)		
TFP growth 5					0.0692***	
					(0.004)	
TFP growth 6						0.0855***
						(0.001)
Young dependency ratio	–0.0156	–0.0168	–0.0157	–0.0154	–0.0167	–0.0155
	(0.484)	(0.451)	(0.480)	(0.490)	(0.455)	(0.485)
Old dependency ratio	–0.234**	–0.234**	–0.233**	–0.234**	–0.234**	–0.233**
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Terms of trade	0.0240***	0.0241***	0.0240***	0.0241***	0.0241***	0.0240***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade to GDP	0.0719***	0.0733***	0.0717***	0.0717***	0.0732***	0.0716***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Broad money to GDP	0.0465***	0.0456***	0.0467***	0.0465***	0.0457***	0.0468***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Credit to GDP	–0.118***	–0.118***	–0.118***	–0.117***	–0.118***	–0.118***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI to GDP	–0.0828**	–0.0798**	–0.0829**	–0.0831**	–0.0801**	–0.0832**
	(0.017)	(0.021)	(0.016)	(0.016)	(0.020)	(0.016)
Real rate	0.0191	0.0191	0.0190	0.0191	0.0191	0.0190
	(0.226)	(0.226)	(0.227)	(0.227)	(0.227)	(0.228)
R^2	0.194	0.192	0.194	0.194	0.193	0.194
Observations	1,833	1,833	1,833	1,833	1,833	1,833

Note: *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Columns 1–3 are based on baseline-level accounting. Columns 4–6 are based on level accounting based on Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999). Columns 1 and 4 are for average years of schooling for the population aged 15+; 2 and 5 are for average years of schooling for the population aged 25+; 3 and 6 are for average years of schooling corrected for differences in labour force participation.

Source: authors' calculations.

The results for Harrod-neutral productivity growth are given in Table 4. Hicks-neutral productivity growth and Harrod-neutral productivity growth are highly correlated. The estimated coefficient of other controls remain the same as with Hicks-neutral productivity. Measures of TFP growth are positive and significant. The coefficient lies between 0.05 and 0.08. This implies that 1 per cent growth in TFP increases the saving ratio by 0.05–0.08 per cent on impact. Harrod-neutral productivity growth estimates a slightly lower impact of productivity on saving than Hicks-neutral. This is because Harrod-neutral productivity growth only captures productivity growth occurring to labour.

Table 4: Regression results from Harrod-neutral productivity

	(1) Saving ratio	(2) Saving ratio	(3) Saving ratio	(4) Saving ratio	(5) Saving ratio	(6) Saving ratio
Per capita GDP	0.118***	0.118***	0.116***	0.118***	0.118***	0.116***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Per capita GDP square	–0.00196*	–0.00200*	–0.00191	–0.00196*	–0.00200*	–0.00191
	(0.092)	(0.087)	(0.101)	(0.092)	(0.086)	(0.101)
TFP growth 1	0.0839***					
	(0.001)					
TFP growth 2		0.0670***				
		(0.005)				
TFP growth 3			0.0832***			
			(0.001)			
TFP growth 4				0.0578***		
				(0.001)		
TFP growth 5					0.0464***	
					(0.004)	
TFP growth 6						0.0573***
						(0.001)
Young dependency ratio	–0.0156	–0.0168	–0.0157	–0.0154	–0.0167	–0.0155
	(0.484)	(0.451)	(0.480)	(0.490)	(0.455)	(0.485)
Old dependency ratio	–0.234**	–0.234**	–0.233**	–0.234**	–0.234**	–0.233**
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Terms of trade	0.0240***	0.0241***	0.0240***	0.0241***	0.0241***	0.0240***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade to GDP	0.0719***	0.0733***	0.0717***	0.0717***	0.0732***	0.0716***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Broad money to GDP	0.0465***	0.0456***	0.0467***	0.0465***	0.0457***	0.0468***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Credit to GDP	–0.118***	–0.118***	–0.118***	–0.117***	–0.118***	–0.118***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI to GDP	–0.0828**	–0.0798**	–0.0829**	–0.0831**	–0.0801**	-0.0832**
	(0.017)	(0.021)	(0.016)	(0.016)	(0.020)	(0.016)
Real rate	0.0191	0.0191	0.0190	0.0191	0.0191	0.0190
	(0.226)	(0.226)	(0.227)	(0.227)	(0.227)	(0.228)
R^2	0.194	0.192	0.194	0.194	0.193	0.194
Observations	1,833	1,833	1,833	1,833	1,833	1,833

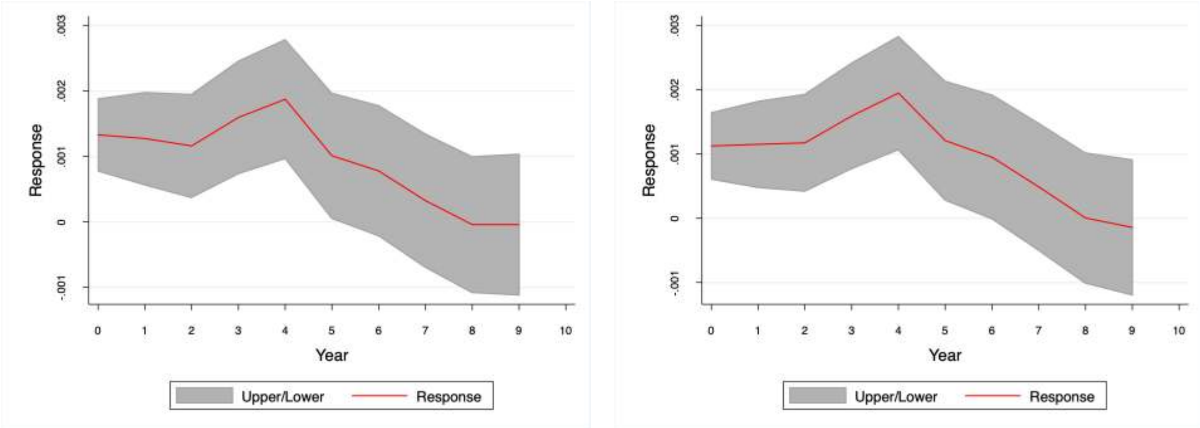
Note: *, **, and *** denote significance at 10, 5, and 1 per,cent, respectively. Columns 1–3 are based on baseline-level accounting. Columns 4–6 are based on level accounting based on Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999). Columns 1 and 4 are with average years of schooling for the population aged 15+; 2 and 5 are for average years of schooling for the population aged 25+; and 3 and 6 are for average years of schooling corrected for differences in labour force participation.

Source: authors' calculations.

The prediction from the model in the previous section suggests that the impact of TFP growth is persistent. To explore this, we estimate a local projection regression given by Equation (4) and plot the impact on the saving ratio due to a 1 per cent increase in Hicks-neutral TFP growth (Harrod-neutral TFP growth gives a similar response and we do not present those results here; they are available on request) in Figure 12. The maximum effect of productivity on the saving ratio occurs at the end of five years. By the seventh year the effect vanishes. Figure A5 in the Appendix contains the response of saving due to the other four measures of TFP growth, and has a similar pattern.

$$S_{i,t+j} = \varphi_i + \beta_0 TFP_{it} + \beta_1 YPC_{it} + \beta_2 YPC_{it}^2 + Z_{it}\theta' + \beta_4 S_{i,t-1} + \varepsilon_{it} \quad \text{for } j = 0, 1, ...9 \tag{4}$$

Figure 12: Response of saving ratio due to TFP growth obtained from Hicks-neutral productivity from local projection



Note: the first column is for average years of schooling for the populations aged 15+; the second column is for average years of schooling for the population aged 25+. The estimated model is given by:

$S_{i,t+j} = \varphi_i + \beta_0 TFP_{it} + \beta_1 YPC_{it} + \beta_2 YPC_{it}^2 + Z_{it}\theta' + \beta_4 S_{i,t--1} + \varepsilon_{it}$ for $j = 0, 1, ...9$

Source: authors' construction.

Results from the model

One of the main objectives of this paper is to estimate the causal impact of productivity growth on saving. We give an almost causal regression in Section 3, where we discuss saving and TFP transitions. In the current section we estimate productivity using variants of the neoclassical growth model discussed above. These are not the same as productivity growth as in the data, so we do not have that nice interpretation, and we discuss that later. We estimate the model using output, consumption, and government expenditure. We can at most use three series to avoid stochastic singularity. We calibrate capital share in national income $\alpha = 0.35$ for all countries in our sample. The share of government expenditure in output is calibrated for each country using their data. Our calibration implies that in steady-state hours worked, n is 1/3. For a model with only cyclical productivity shocks, our calibration implies that the time discount factor β is 0.9709. In the model with trend productivity shock, β depends on the steady-state output growth, as well as steady-state nominal interest rate and depreciation. We use actual steady-state growth data from each country to calibrate β. There are three shocks in the baseline model: cyclical productivity shock, government expenditure shock, and investment-specific technology shock (investment wedge). In the model with trend growth there are two components of productivity shock: cyclical and trend. We obtain productivity shocks from all these estimations and use them to estimate the effect of productivity shock on saving. These shocks are by definition structural, and are exogenous, but in a small sample they could be correlated, as we see later.

Table 5 gives the estimation results from the model with only cyclical TFP shocks. The models are estimated using detrended data and we use linear detrending and Hodrick-–Prescott (HP) filter to detrend the data. Columns 1 and 2 are with the TFP shock obtained from linearly detrended data. Columns 3 and 4 are with the HP filtered data. The impact of the productivity shock is huge in comparison to the one obtained using TFP growth, both with linearly detrended data and HP filtered data. However, these do not have the same interpretation as the one with TFP, as one unit shock is not the same as a 1 per cent change in TFP growth. Other coefficients remain similar to those with TFP from the data.

Table 6 gives the estimation results from the model with only the trend TFP shock. The models are estimated using growth rate of output, consumption, and government expenditure. Since there is a common trend driving all these variables, the model variables are detrended with this trend and growth rates are used as observables to estimate the model. As we saw in the earlier section with the trend productivity shock, the impact of the productivity shock also depends on the persistence of the productivity shock. The countries in our sample are highly heterogeneous in terms of persistence of trend productivity shocks. We find positive impacts of productivity shocks on saving that is in the range of the impact of productivity shocks on saving obtained from the Harrod-neutral productivity obtained in the earlier section. Without trend, the coefficient is significant at 10 per cent; with trend, it is significant at 6 per cent. This suggests that the estimation is able to give us the productivity shock. In our model, the assumed productivity process is Harrod-neutral.

Table 5: Estimates: only cyclical productivity shock

	(1) Saving ratio	(2) Saving ratio	(3) Saving ratio	(4) Saving ratio
TFP shock linear	1.059**	1.050**		
	(0.016)	(0.013)		
TFP shock HP			0.630*	0.631*
			(0.078)	(0.077)
Per capita GDP	0.163***	0.158***	0.163***	0.157***
	(0.002)	(0.003)	(0.002)	(0.003)
Per capita GDP square	–0.00271	–0.00255	–0.00274	–0.00254
	(0.134)	(0.164)	(0.131)	(0.162)
Young dependency ratio	0.108	0.128*	0.0989	0.124*
	(0.105)	(0.058)	(0.145)	(0.071)
Old dependency ratio	–0.519**	–0.556**	–0.516**	–0.561**
	(0.015)	(0.043)	(0.016)	(0.043)
Terms of trade	0.0191*	0.0186	0.0190*	0.0183
	(0.087)	(0.108)	(0.096)	(0.122)
Trade to GDP	0.0923***	0.0918***	0.0962***	0.0955***
	(0.001)	(0.001)	(0.001)	(0.000)
Broad money to GDP	0.0858***	0.0861***	0.0846***	0.0850***
	(0.007)	(0.007)	(0.008)	(0.008)
Credit to GDP	–0.0961***	–0.0973***	–0.0999***	–0.101***
	(0.004)	(0.005)	(0.004)	(0.005)
FDI to GDP	–0.160**	–0.163**	–0.151**	–0.155**
	(0.019)	(0.020)	(0.025)	(0.024)
Time trend		0.000283		0.000347
		(0.753)		(0.708)
R^2	0.321	0.321	0.314	0.314
Observations	1,004	1,004	1,004	1,004

Note: *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Columns 1 and 2 are with TFP shock obtained from linearly detrended data. Columns 3 and 4 are with HP filtered data.

Source: authors' calculations.

Table 6: Estimates: only trend productivity shock

	(1) Saving ratio	(2) Saving ratio
TFP shock (trend productivity shock)	0.0489	0.0578*
	(0.108)	(0.055)
Per capita GDP	0.127**	0.159***
	(0.017)	(0.004)
Per capita GDP square	–0.00207	–0.00282
	(0.264)	(0.138)
Old dependency ratio	–0.508**	–0.420*
	(0.024)	(0.092)
Terms of trade	0.0186	0.0204*
	(0.157)	(0.096)
Trade to GDP	0.0953***	0.0965***
	(0.000)	(0.000)
Broad money to GDP	0.0758**	0.0796**
	(0.021)	(0.012)
Credit to GDP	–0.100***	–0.0966**
	(0.006)	(0.010)
FDI to GDP	–0.158**	–0.147**
	(0.018)	(0.031)
Time trend		–0.000722
		(0.387)
R^2	0.299	0.306
Observations	1,004	1,004

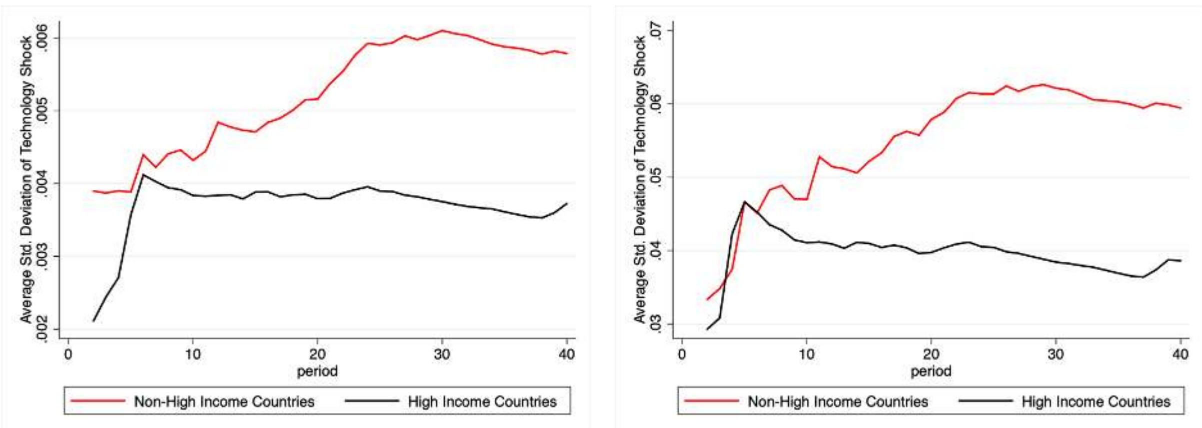
Note: *, **, and *** denote significance at 10, 5, and 1 per cent respectively.

Source: authors' calculations.

Figure 13 gives the mean standard deviation of cyclical and trend shocks over time in our sample by high- and non-high-income countries. We have smoothed estimates of these shocks and country classification. We construct the standard deviation of shocks on a recursive basis across these two sets of countries and then take the average based on country grouping. As we can see, the standard deviation of both cyclical and trend shocks is higher.

Figure 13: Recursive standard deviation of productivity shock

(a) Cyclical shock (b) Trend shock



Source: authors' construction.

More importantly, the standard deviation of both trend and cyclical shocks is higher in non-high-income countries. A similar pattern is obtained in Figure 3. Also, we find that in non-high-income countries, variance of productivity shocks, both cyclical and trend, keep increasing for many years, unlike in high-income countries. Estimating the neoclassical model for 47 countries separately and using productivity shocks gives us similar patterns as given by TFP growth. Therefore, we now turn to estimating a more enriched model.

Further results from the model

We now move to a model with both trend and cyclical shocks. Aguiar and Gopinath (2007) claim that trend volatility is higher in emerging economies in comparison to developed economies, and that this gives rise to counter-cyclical current-account balances. We have 47 countries in our sample: 18 non-high-income and 29 high-income countries. Tables 7 and 8 give the relative dominance of trend and cyclical shocks in these countries without and with habit persistence in consumption.

Table 7: Trend and cycle dominance without habit persistence

Income group	Cycle-dominated	Trend-dominated	Total
Non-high-income countries	6	12	18
High-income countries	16	13	29
Total	22	25	47

Note: the standard deviation of trend and cycle shocks is obtained from estimations. We define trend-dominated countries as those with a ratio of standard deviation of trend and cycle technology shock greater than 1; otherwise they are cycle-dominated.

Source: authors' construction.

Table 8: Trend and cycle dominance with habit persistence

Income group	Cycle-dominated	Trend-dominated	Total
Non-high-income countries	16	2	18
High-income countries	29	0	29
Total	45	2	47

Note: the standard deviation of trend and cycle shocks is obtained from estimation. We define trend-dominated countries as those with a ratio of standard deviation of trend and cycle technology shock greater than 1; otherwise they are cycle-dominated.

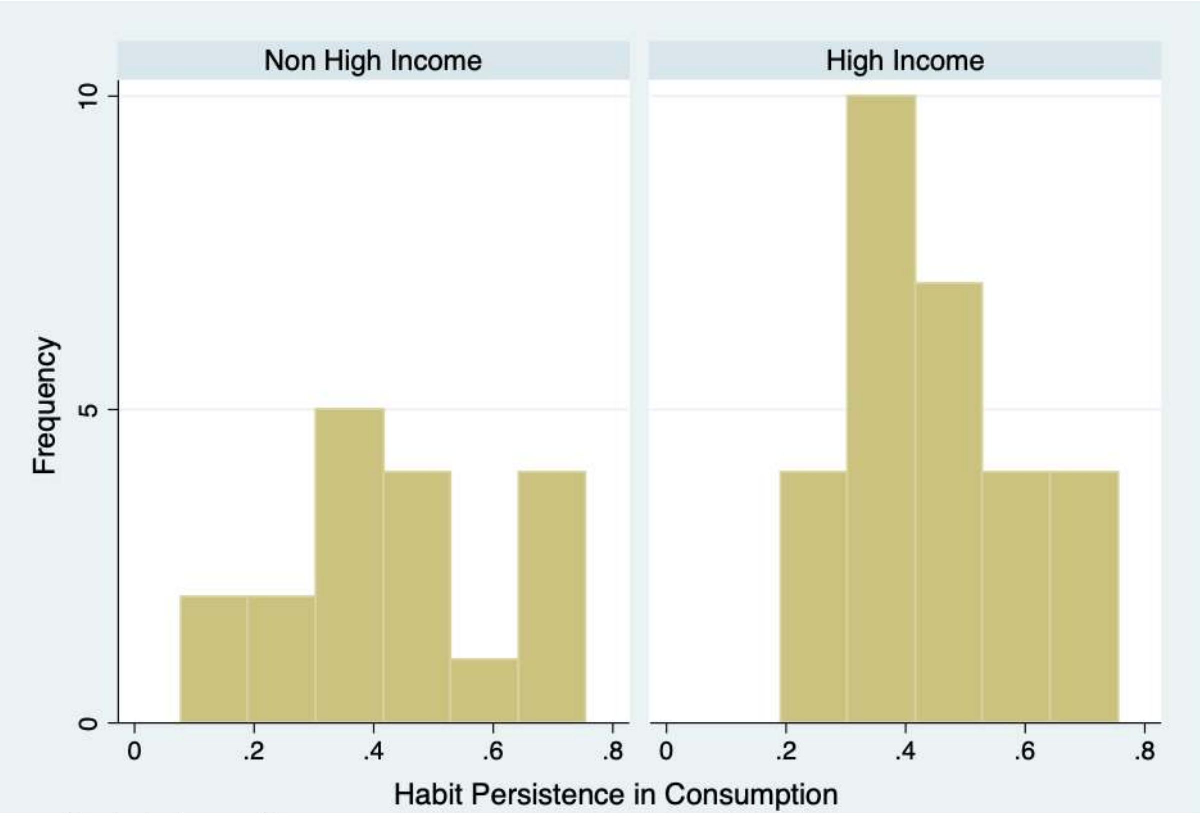
Source: authors' construction.

Without habit persistence in consumption, out of 18 non-high-income countries, 12 are trend-dominated. In other words, two-thirds of non-high-income countries are trend-dominated. Out of 29 high-income countries, only 13 are trend-dominated (less than 50 per cent). Therefore, it is true that a relatively higher proportion of non-high-income countries are dominated by trend shocks.

As we can see from Table 8, including habit persistence makes almost every country cycle-dominated. Carroll et al. (2000) argue that evidence of growth causing saving cannot be reconciled with traditional neoclassical growth models. In these models, forward-looking economic agents would reduce their saving and consume more in anticipation of higher future income growth. This is the effect of trend shocks on saving as discussed in earlier sections. According to these authors, if we augment the neoclassical model with habit in consumption, then anticipated future growth may increase saving. We saw that higher values of habit persistence imply less dis-saving due to a trend shock for a given value of persistence of trend shock. Our estimates of smoothed shock suggest that including habit persistence makes trend shocks less volatile. The productivity process is dominated by cyclical shocks in the presence of habit, unlike its absence. In other words, inclusion of habit persistence changes the identified cyclical and trend shocks, which could be the reason that trend shock does not lead to a fall in saving in the presence of habit.

Figure 14 gives the distribution of estimated habit persistence in consumption for high- and non-high-income countries. We do not find any significant difference in habit persistence among high- and non-high-income countries. This brings an additional empirical challenge as the country grouping is not likely to control for differences in habit persistence. We cannot control for habit persistence using these estimates as they are time invariant, and our fixed effect estimation implies that invariant controls are perfectly correlated with country fixed effects. But habit persistence influences the impact of both trend and cyclical shocks on saving. There is an additional issue with the correct identification of impacts of trend shocks on saving: one needs to control for the persistence of the trend shock, but that is also not feasible in the current framework.

Figure 14: Habit persistence in consumption



Source: authors' construction.

Table 9 gives the estimation results from the model-based trend and cyclical shocks without habit persistence. The coefficient for the trend shock is positive but not significant. The coefficient for the cyclical shock is positive and significant, and slightly higher than the coefficient obtained from Harrod-neutral TFP growth. Other coefficients are similar as before.

We have obtained these productivity shocks from estimation of the neoclassical model. Although these shocks are assumed to be exogenous, they may be correlated with variables which affect productivity. Tables A1–A5 in the Appendix give the bivariate regression of productivity shocks with other variables being used in the analysis. These productivity shocks are correlated with few variables. Therefore, in Table 10 we produce the regression of saving with these productivity shocks where we only control for variables correlated with a given productivity shock. This gives similar results as before.

Table 9: Trend and cycle

	(1) Saving ratio	(2) Saving ratio	(3) Saving ratio	(4) Saving ratio
Trend productivity shock	0.0536		0.0508	
	(0.274)		(0.275)	
Cyclical productivity shock		0.0953***		0.0968***
		(0.009)		(0.010)
Per capita GDP	0.165***	0.163***	0.160***	0.157***
	(0.002)	(0.002)	(0.003)	(0.003)
Per capita GDP square	–0.00275	–0.00271	–0.00257	–0.00250
	(0.129)	(0.134)	(0.156)	(0.168)
Young dependency ratio	0.102	0.0986	0.124*	0.126*
	(0.131)	(0.146)	(0.072)	(0.068)
Old dependency ratio	–0.520**	–0.513**	–0.559**	–0.561**
	(0.016)	(0.016)	(0.044)	(0.043)
Terms of trade	0.0196*	0.0191*	0.0190	0.0184
	(0.080)	(0.091)	(0.101)	(0.117)
Trade to GDP	0.0967***	0.0961***	0.0962***	0.0953***
	(0.000)	(0.001)	(0.000)	(0.000)
Broad money to GDP	0.0842***	0.0843***	0.0845***	0.0848***
	(0.008)	(0.008)	(0.008)	(0.008)
Credit to GDP	–0.100***	–0.101***	–0.102***	–0.102***
	(0.003)	(0.003)	(0.005)	(0.005)
FDI to GDP	–0.145**	–0.154**	–0.149**	–0.158**
	(0.028)	(0.021)	(0.027)	(0.020)
Time trend			0.000303	0.000370
			(0.742)	(0.691)
R^2	0.312	0.314	0.313	0.315
Observations	1,004	1,004	1,004	1,004

Note: *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Columns 3 and 4 are estimated with the time trend; columns 1 and 3 are with the trend productivity shock; columns 2 and 4 are with the cyclical productivity shock.

Source: authors' calculations.

Table 10: Regression with only correlated explanatory variables

	(1) Saving ratio	(2) Saving ratio	(3) Saving ratio	(4) Saving ratio	(5) Saving ratio
Cyclical productivity shock	1.451***				
	(0.001)				
Young dependency ratio	–0.0254		–0.0300		
	(0.732)		(0.685)		
Old dependency ratio	–0.416		–0.407		
	(0.126)		(0.134)		
Broad money to GDP	0.0514		0.0506	0.0425	
	(0.222)		(0.231)	(0.279)	
Credit to GDP	–0.0214	–0.0309	–0.0221	–0.0263	–0.0595*
	(0.519)	(0.133)	(0.509)	(0.432)	(0.069)
Time trend	0.000947	0.000995*	0.000957	0.000877	0.00160
	(0.191)	(0.084)	(0.196)	(0.149)	(0.100)
Cyclical productivity shock		0.981***			
		(0.000)			
Trade to GDP		0.0946***			
		(0.001)			
FDI to GDP		–0.0352			–0.0298
		(0.549)			(0.695)
Trend productivity shock			0.0802**		
			(0.015)		
Trend productivity shock				0.0621	
				(0.199)	
Cyclical productivity shock					0.168***
					(0.006)
R^2	0.112	0.139	0.102	0.079	0.101
Observations	1349	1543	1343	1343	960

Note: *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Column 1 is with cyclical shock obtained from linearly detrended data, column 2 is with cyclical shock obtained from HP filtered data; column 3 is with trend productivity shock from the trend-only model; column 4 is with trend productivity shock from the model having both cyclical and trend shock, and column 5 is with cyclical productivity shock from the model having both cyclical and trend shocks.

Source: authors' calculations.

Results using shocks as instruments for TFP growth

We estimate productivity shocks using a neo-classical growth model that has a similar specification to technological progress being used to calculate TFP growth. Therefore, we believe that our estimates of productivity shock are likely to be strongly correlated with TFP growth. This makes productivity shocks a strong instrument for productivity growth. These productivity shocks also satisfy the exclusion restriction as their effect on savings must occur through TFP growth. In Table 11 we produce an instrument variable regression where we use these productivity shocks one by one as an instrument for TFP growth. The TFP growth coefficient is significant in all cases except when we use the trend productivity shock from the model having both trend and cyclical productivity shocks as instruments. The effect on saving lies between 0.113 and 0.193. This implies that a 1 per cent growth in TFP is associated with an increase in saving to GDP ratio between 0.11 and 0.19 per cent.

Results with habit in consumption

Figure 15 presents the local projection regression for the saving ratio with trend and cyclical shocks for the model with both trend and cyclical shocks and consumption habits. As before, the coefficient of the trend shock does not turn out to be significant, but the coefficient of the cyclical shock is significant. As mentioned before, the effect of the trend productivity shock on saving depends crucially on habit persistence in consumption and persistence of the trend productivity shock.

Table 11: Regression using instruments

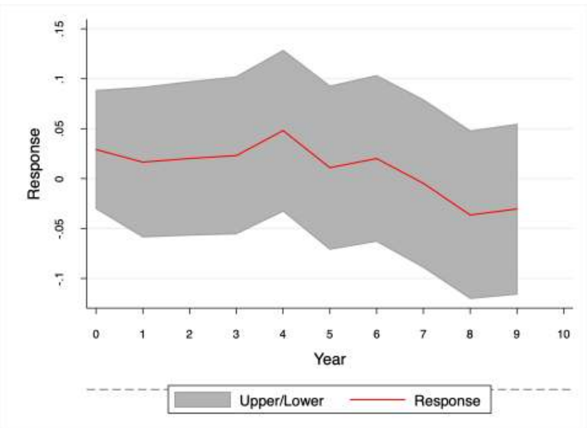
	(1) Saving ratio	(2) Saving ratio	(3) Saving ratio	(4) Saving ratio	(5) Saving ratio
tfp_growth0_hicks	0.193***	0.113**	0.129**	0.113	0.179**
	(0.000)	(0.045)	(0.020)	(0.139)	(0.011)
Young dependency ratio	0.121***	0.116***	0.117***	0.116***	0.120***
	(0.003)	(0.005)	(0.005)	(0.005)	(0.004)
Old dependency ratio	–0.381***	–0.386***	–0.385***	–0.386***	–0.382***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade to GDP	0.106***	0.109***	0.108***	0.109***	0.106***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Broad money to GDP	0.120***	0.119***	0.119***	0.119***	0.120***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Credit to GDP	–0.0872***	–0.0902***	–0.0896***	–0.0902***	–0.0877***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI to GDP	–0.0718	–0.0626	–0.0644	–0.0626	–0.0701
	(0.142)	(0.202)	(0.189)	(0.205)	(0.154)
Time trend	0.00137***	0.00141***	0.00141***	0.00141***	0.00138***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
R^2	0.260	0.254	0.256	0.254	0.259
Observations	901	901	901	901	901

Note: *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Column 1 is with cyclical shock obtained from linearly detrended data; column 2 is with cyclical shock obtained from HP filtered data; column 3 is with trend productivity shock from the trend-only model; column 4 is with trend productivity shock from the model having both cyclical and trend shocks; and column 5 is with cyclical productivity shock from the model having both cyclical and trend shock. The minimum first-stage F (Cragg–Donald Wald F statistic) is 573.70 with the trend productivity shock from the model having both cyclical and trend shocks. All specifications satisfy the Anderson–Rubin weak instrument robust inferences, except for the case of trend productivity shock from the model having both cyclical and trend shocks as the instruments. Tests of joint significance of the endogenous regressor and exogeneity are weak instrument robust inferences.

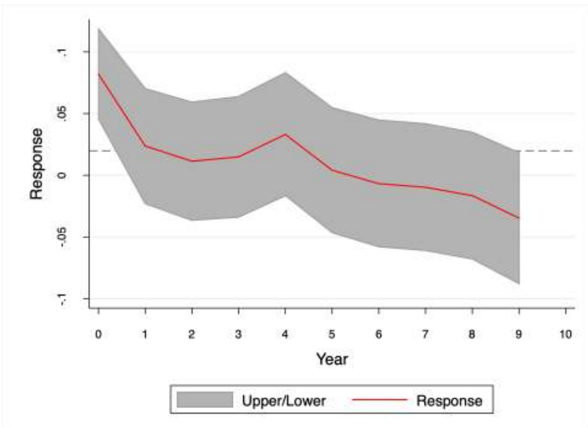
Source: authors' calculations.

Figure 15: Response of the saving ratio due to productivity shocks

(a) Trend shock



(b) Cyclical shock



Source: authors' construction.

6 A tale of two countries again

Table 12 gives the estimated parameters for the neoclassical growth model with both trend and cyclical shocks and habits in consumption for two countries in our sample, Korea and Cameroon. As discussed earlier, these two countries are used as an example to show the growth–saving relationship. Our estimate suggests slightly lower habit persistence in consumption, less persistent trend productivity shock, more persistent cyclical productivity, and significantly more persistent government expenditure shock in Cameroon. Also, the trend shock variance in Cameroon is more than four times the variance of the trend shock in Korea, which is in line with the fact that emerging economies have more volatile trend productivity shocks. The variance of the cyclical productivity shock is also higher in Cameroon in comparison to Korea. The persistence and variance of investment wedge is estimated to be similar in both of these countries.

Table 12: Parameter estimates: trend and cycle with habit

	Korea			Cameroon		
Parameter	Estimate	90% HPD interval		Estimate	90% HPD interval	
γ	0.1806	0.1004	0.2695	0.1264	0.1	0.1616
ρ_z	0.5544	0.3465	0.8104	0.4336	0.1454	0.6727
ρ_{ca}	0.8217	0.5635	0.9921	0.9538	0.9054	0.9966
ρ_i	0.9388	0.8947	0.9851	0.8906	0.8086	0.9826
ρ_g	0.5028	0.4015	0.614	0.9345	0.8761	0.994
σ_z	0.0148	0.0034	0.0232	0.0327	0.0231	0.0434
σ_{ca}	0.0483	0.0372	0.0595	0.0747	0.0614	0.087
σ_i	0.0221	0.015	0.0288	0.0252	0.0125	0.0402
σ_g	0.0941	0.079	0.1087	0.0267	0.0228	0.0309

Note: γ is the measure of habit persistence, α is the extent of backward-looking inflation, ρ_z and ρ_{ca} are AR(1) coefficients of trend and cycle in technology. ρ_i and ρ_g are AR(1) coefficients of investment and government wedge. σ_z, σ_{ca}, σ_i, σ_g are standard deviations of trend, cycle, investment wedge, and government expenditure wedge.

Source: authors' calculations.

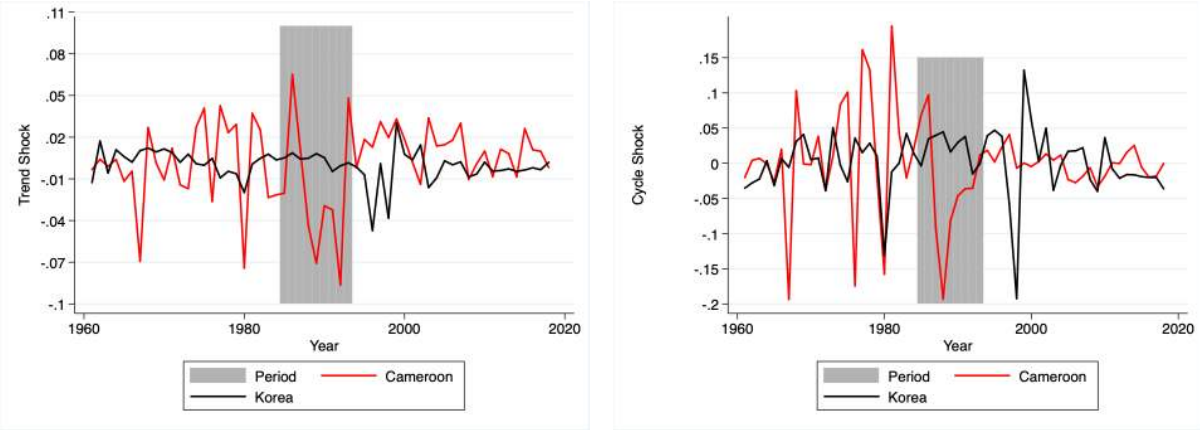
Figure 16 gives the estimated trend and cyclical shocks for Korea and Cameroon. As we can see, both trend and cyclical shocks have higher volatility in Cameroon. Also, the large productivity decline in Cameroon during 1984–93 was due to large negative and significant trend and cyclical shocks. As we can see from these figures, there were negative cyclical and trend shocks in Korea during 1997–98, which was the period of the East Asian crisis. The East Asian crisis was of no consequence to Cameroon. Since the estimate is able to capture these, this gives us confidence that our simple set-up is able to estimate productivity shocks correctly.

We have the parameters of the neoclassical model and estimated productivity shocks for Korea and Cameroon. We can do a counterfactual analysis to explore the role played by negative productivity shocks for the saving ratio in Cameroon. We accomplish this by feeding the trend and cyclical productivity shocks from Korea into the Cameroonian economy.

Figure 17 shows the counterfactual saving ratio for the Cameroonian economy after feeding in the productivity shock from Korea. As we can see, in the absence of a large negative productivity shock in the Cameroonian economy, the saving ratio would not have fallen to the extent we see in the data. Also, a significantly higher fall in the saving ratio is explained by the cyclical productivity shock than by the trend productivity shock, which is in line with the empirical results explained before.

Figure 16: Trend and cycle shock in Cameroon and Korea

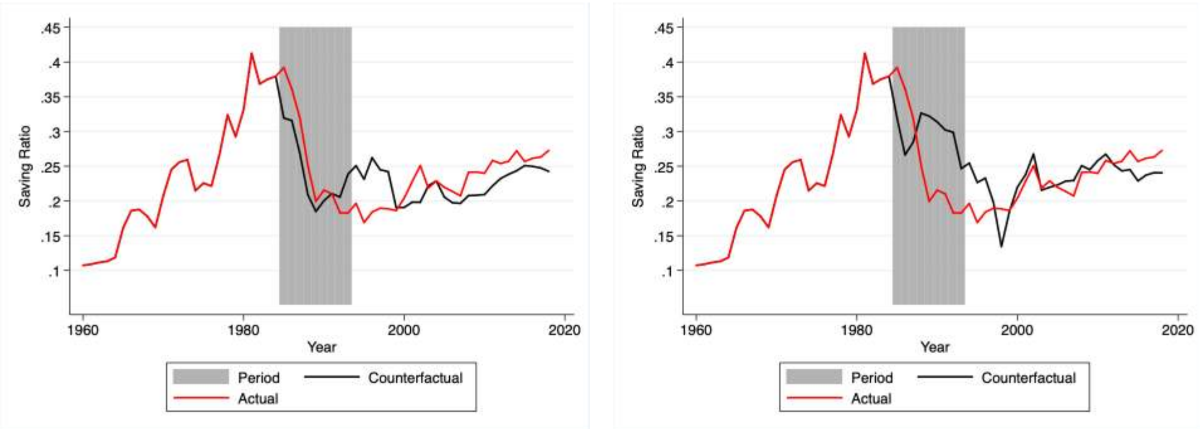
(a) Trend shock (b) Cycle shock



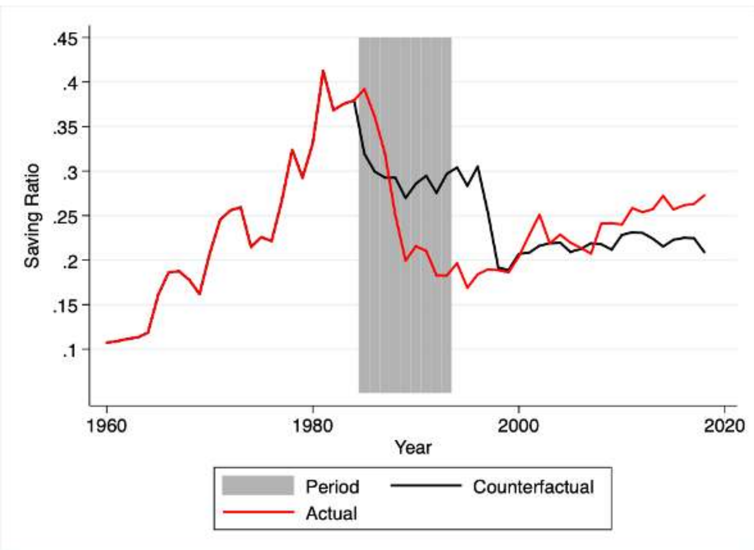
Source: authors' construction.

Figure 17: Counterfactual saving–investment ratio in Cameroon if the technology shock had followed the path it did in Korea after 1985

(a) Only trend shock (b) Only cycle shock



(c) Both trend and cycle shock



Source: authors' construction.

7 Concluding remarks and policy recommendation

Increasing per capita income growth in poor countries has always been a concern for policy-makers around the world. The literature on this issue is broadly divided into two categories. The first strand of literature suggests that increasing the saving ratio is essential for increasing per capita income growth. In other words, this literature believes in causation running from saving to growth. The second strand of literature suggests that growth causes saving and growth can be achieved via simple reforms and allocating resources more wisely. These two strands of literature have not been able to reconcile the issues and reach a conclusion, which we believe is of utmost importance.

Using data from the World Bank, we give near-causal evidence that it is the growth that causes saving and not the other way around. This conclusion is arrived at with very minimal assumptions and should not be questionable. We estimate both Hicks- and Harrod-neutral TFP growth from the data and find positive and significant effects of productivity growth on savings ratio.

We write a neoclassical growth model with productivity shocks where we also decompose the productivity shocks into trend and cyclical components and bring in consumption habits. The neoclassical growth model has an unambiguous prediction that cyclical productivity shocks increase the saving ratio. The effect of trend productivity shocks on saving depends on the persistence of the trend productivity shock (i.e. if the trend productivity shock is expected to be persistent, it decreases current saving as increase in income implies that income is going to be even higher tomorrow, leading to higher consumption today). Higher habit persistence reduces the magnitude of negative effects of the trend component of productivity shocks on savings ratios.

We estimate a neoclassical growth model for 47 countries using the World Bank database (countries with at least 40 years of observations), and estimate cyclical and trend productivity shocks. We use these shocks to estimate the effects of productivity shocks on saving ratios. Our results suggest that the cyclical shock has positive and significant effects, whereas the trend shock has no significant effect. The effect of trend shocks depends on the persistence of the shock and habit persistence in consumption, and since countries in our samples differ on these parameters, we do not find any significant evidence of trend shock affecting savings ratios.

We also implement an instrument variable regression in which we use these productivity shocks as an instrument for TFP growth. Using the instrument increases the coefficient of TFP growth estimated earlier, and the instrumental variable regression suggests that a 1 per cent increase in TFP growth increases the saving ratio by 0.11–0.19 per cent.

Evidence provided in this paper suggests that the saving–growth causation is running from growth to savings and not the other way around. Policy-makers should design policies that can increase productivity growth rather than looking for ways to increase saving, which does not seem to be effective enough to boost savings.

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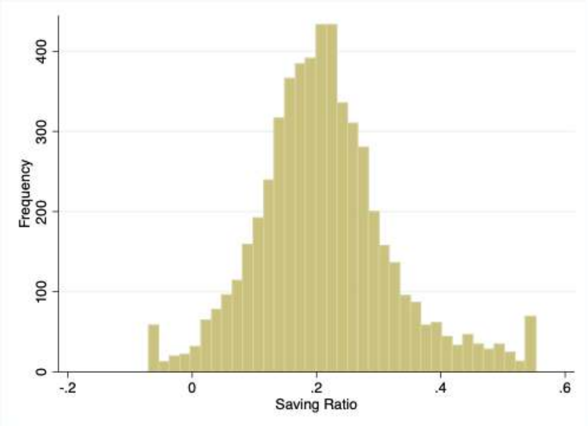
Appendix

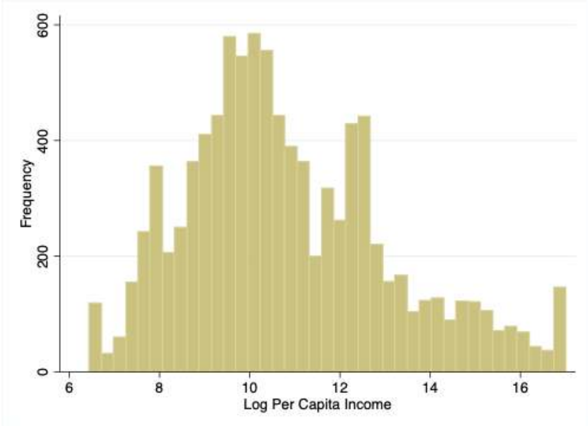
A1 Data

Figure A1: Distribution of data from all countries in our sample

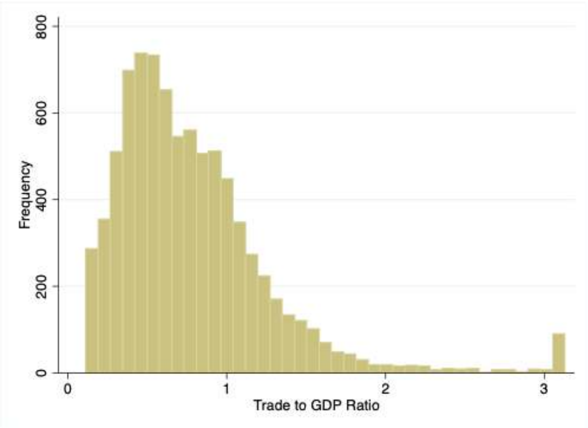
(a) Saving ratio



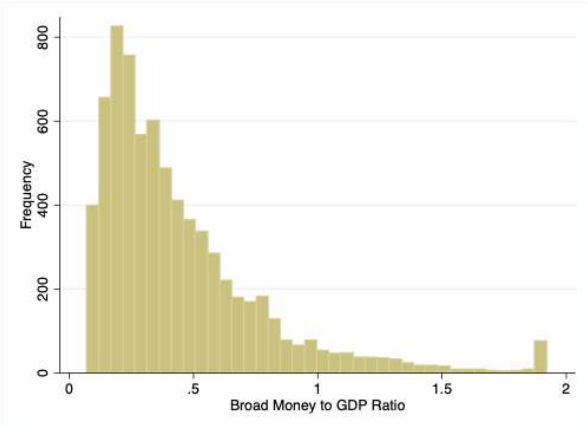
(b) Log per capita income



(c) Trade to GDP ratio



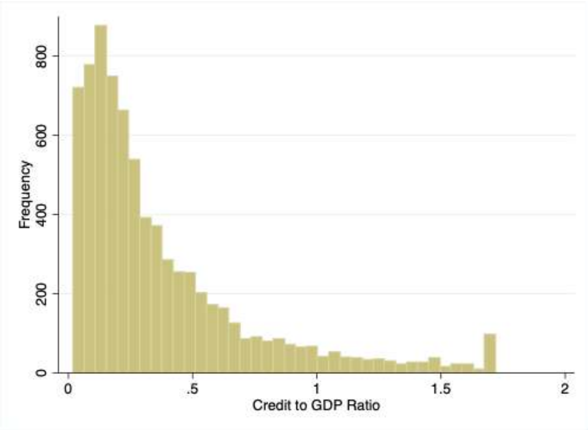
(d) Broad money to GDP ratio



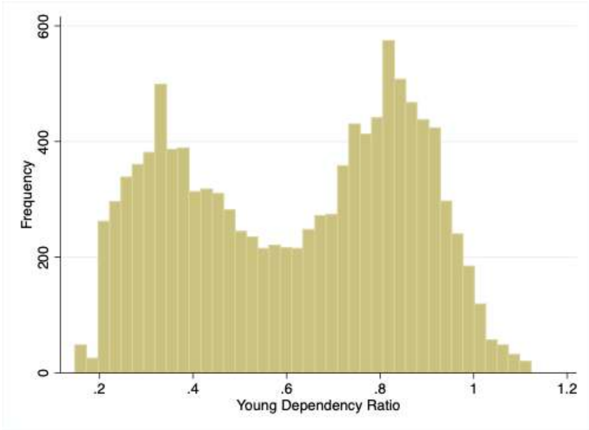
Source: authors' construction.

Figure A2: Distribution of data from all countries in our sample

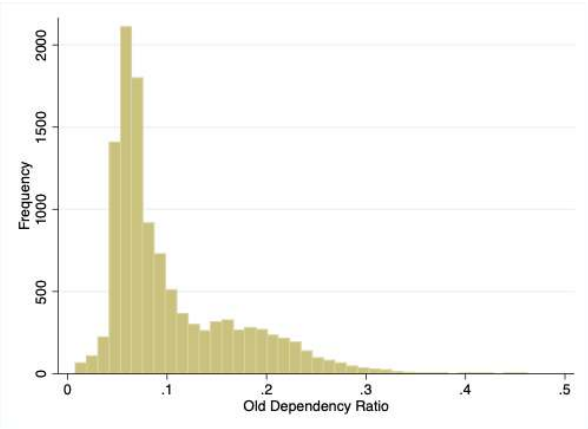
(a) Credit to GDP ratio



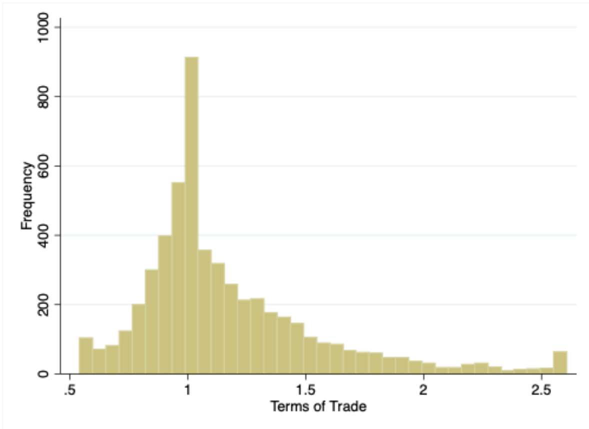
(b) Young dependency ratio



(c) Old dependency ratio



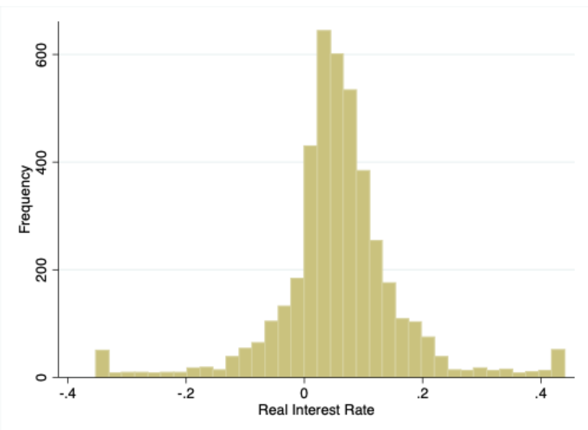
(d) Terms of trade



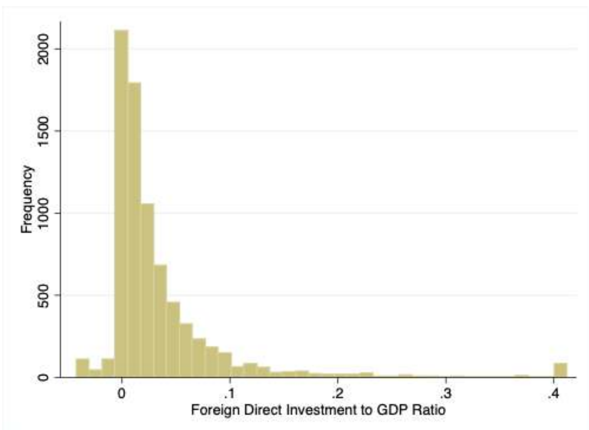
Source: authors' construction.

Figure A3: Distribution of data from all countries in our sample

(a) Real interest rate



(b) Foreign direct investment ratio



Source: authors' construction.

A2 Model

A2.1 Baseline

Household

Lagrangian of the household problem is given by:

$$l = \sum_{t=0}^{\infty} \beta^t \left[\log(c_t) + \chi \log(1-n_t) + \lambda_t \left[w_t n_t + r_t k_{t-1} + T_t - c_t - (1+\tau_{i,t}) I_t\right]\right] + \beta^t \Lambda_t \left[(1-\delta)k_{t-1} + I_t - k_t\right]$$

First order condition with c_t:

$$\frac{\partial l}{\partial c_t} = \frac{1}{c_t} - \lambda_t = 0 \implies \frac{1}{c_t} = \lambda_t$$

First order condition with n_t:

$$\frac{\partial l}{\partial n_t} = -\frac{\chi}{1-n_t} + \lambda_t w_t \implies \frac{\chi}{1-n_t} = \frac{1}{c_t} w_t$$

First order condition with I_t:

$$\frac{\partial l}{\partial I_t} = -\lambda_t (1+\tau_{i,t}) + \Lambda_t \implies \frac{1}{c_t}(1+\tau_{i,t}) = \Lambda_t$$

First order condition with k_t:

$$\frac{\partial l}{\partial k_t} = -\Lambda_t + \beta \Lambda_{t+1}(1-\delta) + \beta \lambda_{t+1} r_{t+1}$$

Using first order condition with I_t and c_t:

$$\frac{1}{c_t}(1+\tau_{i,t}) = \frac{\beta}{c_{t+1}} \left((1+\tau_{i,t+1})(1-\delta) + r_{t+1}\right)$$

First order condition with λ_t:

$$w_t n_t + r_t k_{t-1} + T_t = c_t + (1+\tau_{i,t}) I_t$$

Firm

Production function:

$$y_t = A_t^{1-\alpha} k_{t-1}^{\alpha} n_t^{1-\alpha}$$

First order condition with k_t:

$$r_t = \alpha A_t^{1-\alpha} k_{t-1}^{\alpha-1} n_t^{1-\alpha}$$

First order condition with n_t:

$$w_t = (1-\alpha) A_t^{1-\alpha} k_t^{\alpha} n_t^{-\alpha}$$

Final system

$$\frac{\chi}{1-n_t} = \frac{1}{c_t} w_t$$

$$\frac{1}{c_t}\psi_{i,t} = \frac{\beta}{c_{t+1}}\left(\psi_{i,t+1}(1-\delta) + r_{t+1}\right)$$

$$k_t = (1-\delta)k_{t-1} + I_t$$

$$y_t = A_t^{1-\alpha} k_{t-1}^{\alpha} n_t^{1-\alpha}$$

$$r_t = \alpha A_t^{1-\alpha} k_{t-1}^{\alpha-1} n_t^{1-\alpha}$$

$$w_t = (1-\alpha) A_t^{1-\alpha} k_t^{\alpha} n_t^{-\alpha}$$

$$c_t + I_t + G_t = y_t$$

$$G_t = (1 - \frac{1}{g_t}) y_t$$

Where we have $(1+\tau_{i,t}) = \psi_{i,t}$. The steady state value of $\psi_{i,t}$ is 1. One of the equation out of household budget constraint and aggregate resource constraint is redundant due to Walras' law. We drop the household budget constraint. Eight endogenous variables in the system $c_t, n_t, y_t, k_t, I_t, G_t, w_t, r_t$ are determined by the above eight equations. There are three exogenous processes, technology shock/wedge, investment wedge, and government expenditure shock in the model.

Exogenous processes are given by:

$$\log(A_t) = \rho_A \log(A_{t-1}) + {}_{A,t}$$

$$\log(\psi_{i,t}) = \rho_i \log(\psi_{i,t-1}) + {}_{i,t}$$

$$\log(g_t) = (1-\rho_g)\log(g) + \log(g_{t-1}) + {}_{g,t}$$

Steady state

Household first order condition with n_t :

$$\frac{\chi}{1-n} = \frac{w}{c} \implies \chi c = (1-n)w \implies \chi c + wn = w$$

Using $w = (1-\alpha)\frac{y}{n}$:

$$\chi c + (1-\alpha)y = (1-\alpha)\frac{y}{n} \implies \chi \frac{c}{y} + (1-\alpha) = \frac{(1-\alpha)}{n}$$

From above we obtained the consumption output ratio:

$$\frac{c}{y} = \frac{\left(\frac{(1-\alpha)}{n} - (1-\alpha)\right)}{\chi}$$

From the consumption Euler we have:

$$\psi_i = \beta\left(\psi_i(1-\delta) + r\right) \implies r + (1-\delta) = \frac{1}{\beta}$$

We calibrate r and δ and obtain β. Capital accumulation is:

$$I = \delta k$$

Firm first order condition with k_t:

$$r = \alpha\frac{y}{k} \implies \frac{k}{y} = \frac{\alpha}{r}$$

Firm first order condition with n_t using $\frac{y}{n} = \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}$:

$$w = (1-\alpha)\frac{y}{n} \implies w = (1-\alpha)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}$$

Production function:

$$y = k^{\alpha}n^{1-\alpha} \implies 1 = \frac{k^{\alpha}n^{1-\alpha}}{yy^{\alpha}}y^{\alpha} \implies 1 = \left(\frac{k}{y}\right)^{\alpha} n^{1-\alpha}y^{\alpha-1}$$

Therefore, using $\frac{k}{y} = \frac{\alpha}{r}$, we have:

$$y = \left(\frac{k}{y}\right)^{\frac{\alpha}{1-\alpha}} n \implies \frac{y}{n} = \left(\frac{k}{y}\right)^{\frac{\alpha}{1-\alpha}} = \frac{y}{n} = \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}$$

Aggregate resource constraint:

$$c + I + G = y \implies \frac{c}{y} = 1 - \delta\frac{k}{y} - \frac{G}{Y}$$

We have $\frac{c}{y} = \frac{\left(\frac{(1-\alpha)}{n} - (1-\alpha)\right)}{\chi}$ and therefore:

$$1 - \delta\frac{k}{y} - \frac{G}{Y} = \frac{\left(\frac{(1-\alpha)}{n} - (1-\alpha)\right)}{\chi} \implies \chi = \frac{\left(\frac{(1-\alpha)}{n} - (1-\alpha)\right)}{\left(1 - \delta\frac{k}{y} - \frac{G}{Y}\right)}$$

We calibrate $n = \frac{1}{3}$ and obtain χ.

Log linearization

Household first order condition with n_t:

$$\hat{c}_t = \hat{w}_t - \frac{wn}{(1-n)w}\hat{n}_t$$

Consumption Euler:

$$\hat{c}_t = \hat{c}_{t+1} + \hat{\psi}_{i,t} - \beta(1-\delta)\hat{\psi}_{i,t+1} - \beta r\hat{r}_{t+1}$$

Capital accumulation:

$$\hat{k}_t = (1-\delta)\hat{k}_{t-1} + \delta\hat{I}_t$$

Production function:

$$\hat{y}_t = (1-\alpha)\hat{A}_t + \alpha\hat{k}_t + (1-\alpha)\hat{n}_t$$

Firm first order condition with k_t:

$$\hat{r}_t = \hat{y}_t - \hat{k}_{t-1}$$

Firm first order condition with n_t:

$$\hat{w}_t = \hat{y}_t - \hat{n}_t$$

Aggregate resource constraint:

$$c\hat{c}_t + I\hat{I}_t + G\hat{G}_t = y\hat{y}_t$$

Government expenditure:

$$G\hat{G}_t = y\hat{y}_t - \frac{1}{g}y\hat{y}_t + \frac{1}{g}y\hat{g}_t$$

We next add exports in government expenditure to get government expenditure which evolves exogenously. Our assumption implies that both government expenditure and net exports evolve exogenously by an exogenous process. We estimate the model using $\hat{c}_t, \hat{y}_t$, and $\hat{G}_t$. We estimate two versions of the model, one with linearly detrended data and another with detrended data with HP filter.

A2.2 Model with steady-state growth

In this section we assume that:

$$\log(A_t) = \log(z_t) + \log(A_{t-1})$$

Where:

$$\log(z_t) = (1-\rho_z)\log z + \log(z_{t-1}) + {}_{z,t}$$

The rest of the structure of the model remains the same. Since the model is non-stationary and model variables c, w, I, k, y grow at the rate $\frac{A_t}{A_{t-1}} = z_t$. Therefore, we make the model stationary first and then solve it. For example, $\tilde{w} = \frac{w_t}{A_t}$.

First order condition with n_t:

$$\frac{\chi}{1-n_t} = \frac{1}{c_t}w_t \implies \frac{\chi}{1-n_t} = \frac{1}{\tilde{c}_t}\tilde{w}_t$$

Consumption Euler:

$$\frac{1}{c_t}\psi_{i,t} = \frac{\beta}{c_{t+1}}\left(\psi_{i,t+1}(1-\delta) + r_{t+1}\right) \implies \frac{1}{\tilde{c}_t}\psi_{i,t} = \frac{\beta}{z_{t+1}\tilde{c}_{t+1}}\left(\psi_{i,t+1}(1-\delta) + r_{t+1}\right)$$

Capital accumulation:

$$k_t = (1-\delta)k_{t-1} + I_t \implies \tilde{k}_t = (1-\delta)\frac{\tilde{k}_{t-1}}{z_t} + \tilde{I}_t$$

Production function:

$$y_t = A_t^{1-\alpha}k_{t-1}^{\alpha}n_t^{1-\alpha} \implies \tilde{y}_t = \frac{\tilde{k}_{t-1}^{\alpha}n_t^{1-\alpha}}{z_t^{\alpha}}$$

Firm first order condition with k_t:

$$r_t = \alpha\frac{y_t}{k_{t-1}} = \alpha\frac{\tilde{y}_t}{\tilde{k}_{t-1}}z_t$$

Firm first order condition with n_t:

$$w_t = (1-\alpha)\frac{y_t}{n_t} \implies \tilde{w}_t = (1-\alpha)\frac{\tilde{w}_t}{n_t}$$

Aggregate resource constraint:

$$c_t + I_t + G_t = y_t \implies \tilde{c}_t + \tilde{I}_t + \tilde{G}_t = \tilde{y}_t$$

Government expenditure:

$$G_t = (1-\frac{1}{g_t})y_t \implies \tilde{G}_t = (1-\frac{1}{g_t})\tilde{y}_t$$

The rest of the exogenous process remains same.

Steady state

Household first order condition with n_t:

$$\chi\tilde{c} = (1-n)\tilde{w} \implies \chi\tilde{c} + \tilde{w}n = \tilde{w}$$

Using $\tilde{w} = (1-\alpha)\frac{\tilde{y}}{n}$:

$$\chi\tilde{c} + (1-\alpha)\tilde{y} = (1-\alpha)\frac{\tilde{y}}{n} \implies \frac{\tilde{c}}{\tilde{y}} = \frac{\left(\frac{(1-\alpha)}{n} - (1-\alpha)\right)}{\chi}$$

Consumption Euler:

$$\frac{r+(1-\delta)}{g_y} = \frac{1}{\beta}$$

Where g_y is steady-state growth (steady state value of z_t). We calibrated this for each country using their steady growth, which is average of growth rate in our sample. r and δ are also calibrated and β is calculated. Our calibration implies that β varies across countries.

Capital accumulation:

$$\tilde{k} = (1-\delta)\frac{\tilde{k}}{g_y} + I \implies I = \left(1 - \frac{(1-\delta)}{g_y}\right)\tilde{k}$$

Production function:

$$1 = \frac{\tilde{k}^{\alpha} n^{1-\alpha}}{g_y^{\alpha}\tilde{y}\tilde{y}^{\alpha}}\tilde{y}^{\alpha} = \frac{1}{g_y^{\alpha}}\left(\frac{\tilde{k}}{\tilde{y}}\right)^{\alpha} n^{1-\alpha}\tilde{y}^{\alpha-1}$$

$$\tilde{y} = \frac{1}{g_y^{\frac{\alpha}{1-\alpha}}}\left(\frac{\tilde{k}}{\tilde{y}}\right)^{\frac{\alpha}{1-\alpha}} n \implies \tilde{y} = \frac{1}{g_y^{\frac{\alpha}{1-\alpha}}}\left(\frac{\alpha g_y}{r}\right)^{\frac{\alpha}{1-\alpha}} n$$

$$\frac{\tilde{y}}{n} = \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}$$

First order condition with respect to k_t:

$$r = \alpha\frac{\tilde{y}}{\tilde{k}}g_y \implies \frac{\tilde{k}}{\tilde{y}} = \frac{\alpha g_y}{r}$$

Firm first order condition with n_t:

$$\tilde{w} = (1-\alpha)\frac{\tilde{y}}{n} \implies \tilde{w} = (1-\alpha)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}$$

Aggregate resource constraint:

$$\frac{\tilde{c}}{\tilde{y}} = 1 - \left(1 - \frac{(1-\delta)}{z}\right)\frac{\tilde{k}}{\tilde{y}} - \frac{\tilde{G}}{\tilde{y}}$$

Using $\frac{c}{y} = \frac{\left(\frac{(1-\alpha)}{n} - (1-\alpha)\right)}{\chi}$:

$$1 - \left(1 - \frac{(1-\delta)}{g_y}\right)\frac{\tilde{k}}{\tilde{y}} - \frac{\tilde{G}}{\tilde{y}} = \frac{\left(\frac{(1-\alpha)}{n} - (1-\alpha)\right)}{\chi} \implies \chi = \frac{\left(\frac{(1-\alpha)}{n} - (1-\alpha)\right)}{1 - \left(1 - \frac{(1-\delta)}{g_y}\right)\frac{\tilde{k}}{\tilde{y}} - \frac{\tilde{G}}{\tilde{y}}}$$

We calibrate $n = \frac{1}{3}$ and obtain χ.

Log linearization

Household first order condition with n_t:

$$\hat{\tilde{c}}_t = \hat{\tilde{w}}_t - \frac{wn}{(1-n)w}\hat{n}_t$$

Consumption Euler:

$$\hat{c}_t = \hat{c}_{t+1} + \hat{z}_{t+1} + \hat{\psi}_{i,t} - \frac{\beta(1-\delta)}{g_y}\hat{\psi}_{i,t+1} - \frac{\beta}{g_y} r\hat{r}_{t+1}$$

Capital accumulation:

$$\hat{k}_t = \frac{(1-\delta)}{g_y}\hat{k}_{t-1} - \frac{(1-\delta)}{g_y}\hat{z}_t + \left(1 - \frac{(1-\delta)}{g_y}\right)\hat{I}_t$$

Production function:

$$\tilde{y}_t = \frac{1}{z_t^{\alpha}}\tilde{k}_{t-1}^{\alpha} n_t^{1-\alpha}$$

$$\hat{y}_t = -\alpha\hat{z}_t + \alpha\hat{k}_{t-1} + (1-\alpha)\hat{n}_t$$

First order condition with respect to k_t:

$$\hat{r}_t = \hat{z}_t + \hat{y}_t - \hat{k}_{t-1}$$

Firm first order condition with respect to n_t:

$$\hat{w}_t = \hat{y}_t - \hat{n}_t$$

Aggregate resource constraint:

$$\tilde{c}\,\hat{\tilde{c}}_t + \tilde{I}\,\hat{\tilde{I}}_t + \tilde{G}\,\hat{\tilde{G}}_t = \tilde{y}\,\hat{\tilde{y}}_t$$

Government expenditure:

$$\tilde{G}\,\hat{\tilde{G}}_t = \tilde{y}\,\hat{\tilde{y}}_t - \frac{1}{g}\tilde{y}\,\hat{\tilde{y}}_t + \frac{1}{g}\tilde{y}\hat{g}_t$$

Model observables are given by

$$g_{y,t} = \frac{y_t/A_t}{y_{t-1}/A_{t-1}}\frac{A_t}{A_{t-1}} = \frac{\tilde{y}_t}{\tilde{y}_{t-1}} z_t$$

The above equation shows that $g_y = z$ in steady state. Log linearization gives

$$\hat{g}_{yt} = \hat{\tilde{y}}_t - \hat{\tilde{y}}_{t-1} + \hat{\tilde{z}}_t$$

Similarly, the other two other model observables are obtained as given below:

$$\hat{g}_{Gt} = \hat{\tilde{G}}_t - \hat{\tilde{G}}_{t-1} + \hat{\tilde{z}}_t$$

$$\hat{g}_{ct} = \hat{\tilde{c}}_t - \hat{\tilde{c}}_{t-1} + \hat{\tilde{z}}_t$$

The model is estimated using deviation of output growth, consumption growth, and adjusted government expenditure growth from their steady-state values.

A2.3 Trend and cycle

Production function is given by:

$$y_t = A_t^{1-\alpha} k_{t-1}^{\alpha} n_t^{1-\alpha}$$

In this section, we assume that:

$$A_t = A_t^t \times A_t^c \implies \log(A_t) = \log(A_t^t) + \log(A_t^c)$$

We assume that trend grows at a steady-state rate, as before:

$$\log(A_t^t) = \log(z_t) + \log(A_{t-1}^t)$$

Where:

$$\log(z_t) = (1 - \rho_z) \log z + \log(z_{t-1}) + {}_{z,t}$$

The cyclical component grows as a stationary process with steady-state value 1:

$$\log(A_t^c) = \rho_{ac} \log(A_{t-1}^c) + {}_{ac,t}$$

Take log of production function:

$$\log(y_t) = (1 - \alpha) \log(A_t) + \alpha \log(k_t) + (1 - \alpha) \log(n_t)$$

$$\log(y_t) = (1 - \alpha) \left[\log(A_t^t) + \log(A_t^c)\right] + \alpha \log(k_t) + (1 - \alpha) \log(n_t)$$

Along the balanced growth path, capital and output grow at the same rate:

$$g_y = (1 - \alpha) g_a + \alpha g_y$$

$$g_y = g_a$$

This means output grows at the steady-state rate g_a., implying $z = g_a$. The rest of the structure of the model remains the same. Since the model is non-stationary and model variables c, w, I, k, y grow at the rate $\frac{A_t}{A_{t-1}} = z_t$. Therefore, we make the model stationary first and then solve it. For example, $\tilde{w} = \frac{w_t}{A_t}$. Detrended variables and steady-state values of all variables remain same as before, since the cyclical component of technology has a steady-state value of 1. The log linearized version of y_t is only different as it contains the cyclical component of technology. The log linearized version of $\tilde{y}$ is given by:

$$\frac{y_t}{A_t^t} = \frac{A_t^{1-\alpha} k_{t-1}^{\alpha} n_t^{1-\alpha}}{A_t^t}$$

$$\frac{y_t}{A_t^t} = \left(A_{t-1}^t\right)^{\alpha} \frac{\left(A_t^t \times A_t^c\right)^{1-\alpha} \tilde{k}_{t-1}^{\alpha} n_t^{1-\alpha}}{A_t^t}$$

$$\tilde{y}_t = \frac{\left(A_t^c\right)^{1-\alpha} \tilde{k}_{t-1}^{\alpha} n_t^{1-\alpha}}{\left(z_t\right)^{\alpha}}$$

$$\hat{y}_t = -\alpha \hat{z}_t + (1-\alpha) A_{c,t} + \alpha \hat{k}_{t-1} + (1-\alpha) \hat{n}_t$$

The model is estimated using deviation of output growth, consumption growth, and adjusted government expenditure growth from their steady-state values as in the previous section.

A2.4 Trend cycle and habit

In this section, we are going to assume habit persistence in consumption. The Lagrangian is now given by:

$$l = \sum_{t=0}^{\infty} \beta^t \left[\log(c_t - \gamma c_{t-1}) + \chi \log(1-n_t)\right] + \beta^t \lambda_t \left[w_t n_t + r_t k_{t-1} + T_t - c_t - (1+\tau_{i,t}) I_t\right] + \beta^t \Lambda_t \left[(1-\delta) k_{t-1} + I_t - k_t\right]$$

One can write $c_t - \gamma c_{t-1}$ as $c_t - \gamma c_t + \gamma c_t - \gamma c_{t-1}$. From there we can write $c_t (1-\gamma) + \gamma (c_t - c_{t-1})$. Higher value of γ implies that consumer derives higher utility from growth in consumption rather than from consumption.

First order conditions (FOCs)

First order condition with respect to c_t:

$$\frac{\partial l}{\partial c_t} = \frac{1}{c_t - \gamma c_{t-1}} - \beta \gamma \frac{1}{c_{t+1} - \gamma c_t} - \lambda_t = 0$$

First order condition with respect to n_t:

$$\frac{\partial l}{\partial n_t} = -\frac{\chi}{1-n_t} + \lambda_t w_t = 0$$

First order condition with respect to I_t:

$$\frac{\partial l}{\partial I_t} = -\lambda_t (1+\tau_{i,t}) + \Lambda_t = 0$$

First order condition with respect to k_t:

$$\frac{\partial l}{\partial k_t} = -\Lambda_t + \beta \Lambda_{t+1} (1-\delta) + \beta \lambda_{t+1} r_{t+1}$$

Final system using the first order condition from the firm which remains same is given by:

$$\frac{1}{c_t - \gamma c_{t-1}} \text{-} \beta \gamma \frac{1}{c_{t+1} - \gamma c_t} \text{=} \lambda_t$$

$$\frac{\chi}{1-n_t} = \lambda_t w_t$$

$$\lambda_t \psi_{i,t} = \Lambda_t$$

$$\Lambda_t = \beta \Lambda_{t+1}(1-\delta) + \beta \lambda_{t+1} r_{t+1}$$

$$y_t = A_t^{1-\alpha} k_{t-1}^{\alpha} n_t^{1-\alpha}$$

$$r_t = \alpha \frac{y_t}{k_{t-1}}$$

$$w_t = (1-\alpha)\frac{y_t}{n_t}$$

$$k_t = (1-\delta)k_{t-1} + I_t$$

$$c_t + I_t + G_t = y_t$$

$$G_t = (1 - \frac{1}{g_t})y_t$$

Technological progress is given by:

$$\log(A_t) = \log(A_t^t) + \log(A_t^c)$$

We assume that trend grows at a steady state rate, as before:

$$\log(A_t^t) = \log(z_t) + \log(A_{t-1}^t)$$

Where:

$$\log(z_t) = (1-\rho_z)\log z + \log(z_{t-1}) + {}_{z,t}$$

The cyclical component grows as a stationary process with steady-state value 1:

$$\log(A_t^c) = \rho_{ac}\log(A_{t-1}^c) + {}_{ac,t}$$

Stationary system

First order condition with respect to c_t ($\Omega_t = \lambda_t A_t^t$ and $\tilde{c}_t = \frac{c_t}{A_t^t}$):

$$\Omega_t = \frac{z_t}{z_t \tilde{c}_t - \gamma \tilde{c}_{t-1}} - \beta\gamma E_t\left(\frac{1}{z_{t+1}\tilde{c}_{t+1} - \gamma \tilde{c}_t}\right)$$

First order condition with respect to n_t:

$$\frac{\chi}{1-n_t} = \Omega_t \tilde{w}_t$$

First order condition with respect to I_t:

$$\Omega_t \psi_{it} = \Theta_t$$

where $\Lambda_t \times A_t^t = \Theta_t$

First order condition with respect to k_t:

$$\Theta_t z_{t+1} = \beta \Theta_{t+1}(1-\delta) + \beta \Omega_{t+1} r_{t+1}$$

Capital accumulation:

$$\tilde{k}_t = (1-\delta)\frac{\tilde{k}_{t-1}}{z_t} + \tilde{I}_t$$

Production function:

$$\tilde{y}_t = \frac{(A_t^c)^{1-\alpha}\tilde{k}_{t-1}^{\alpha} n_t^{1-\alpha}}{(z_t)^{\alpha}}$$

Firm first order condition with respect to k_t:

$$r_t = \alpha \frac{\tilde{y}_t}{\tilde{k}_{t-1}} z_t$$

Firm first order condition with respect to n_t:

$$\tilde{w}_t = (1-\alpha)\frac{\tilde{y}_t}{n_t}$$

Aggregate resource constraint:

$$\tilde{c}_t + \tilde{I}_t + \tilde{G}_t = \tilde{y}_t$$

Government expenditure:

$$\tilde{G}_t = (1 - \frac{1}{g_t})\tilde{y}_t$$

Steady-state stationary system

First order condition with respect to c_t:

$$\frac{[g_y - \beta\gamma]}{\Omega(g_y - \gamma)} = \tilde{c}$$

First order condition with respect to n_t:

$$\frac{1}{\Omega}\left(\frac{\chi}{1-n}\right) = \tilde{w}$$

Using $\frac{[g_y-\beta\gamma]}{\tilde{c}(g_y-\gamma)} = \Omega$ and $\tilde{w} = (1-\alpha)\frac{\tilde{y}}{n}$:

$$\frac{\tilde{c}}{\tilde{y}} = \frac{(1-n)[g_y - \beta\gamma](1-\alpha)}{\chi(g_y-\gamma)n}$$

First order condition with respect to I_t:

$$\Omega = \Theta$$

First order condition with respect to k_t:

$$g_y = \beta(1-\delta) + \beta r$$

$$\beta = \frac{g_y}{1-\delta+r}$$

Capital accumulation:

$$I = \left(1 - \frac{(1-\delta)}{g_y}\right)\tilde{k}$$

Production function:

$$\frac{\tilde{y}}{n} = \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}$$

Firm first order condition with respect to k_t:

$$\frac{\tilde{k}}{\tilde{y}} = \frac{\alpha g_y}{r}$$

Firm first order condition with respect to n_t:

$$\tilde{w} = (1-\alpha)\frac{\tilde{y}}{n} \implies \tilde{w} = (1-\alpha)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}$$

Aggregate resource constraint:

$$\frac{\tilde{c}}{\tilde{y}} = 1 - \left(1 - \frac{(1-\delta)}{a}\right)\frac{\tilde{k}}{\tilde{y}} - \frac{\tilde{G}}{\tilde{y}}$$

Using $\frac{\tilde{c}}{\tilde{y}} = \frac{(1-n)[a-\beta\gamma](1-\alpha)}{\chi(a-\gamma)n}$:

$$1 - \left(1 - \frac{(1-\delta)}{a}\right)\frac{\tilde{k}}{\tilde{y}} - \frac{\tilde{G}}{\tilde{y}} = \frac{(1-n)\,[a-\beta\gamma]\,(1-\alpha)}{\chi\,(a-\gamma)\,n}$$

$$\chi = \frac{(1-n)\,[a-\beta\gamma]\,(1-\alpha)}{\left(1 - \left(1 - \frac{(1-\delta)}{a}\right)\frac{\tilde{k}}{\tilde{y}} - \frac{\tilde{G}}{\tilde{y}}\right)(a-\gamma)\,n}$$

We calibrate $n = \frac{1}{3}$ and obtain χ.

Log linearized version

First order condition with respect to c_t:

$$(g_y^2 + \beta\gamma^2)\hat{c}_t = g_y\gamma\hat{c}_{t-1} + \beta\gamma g_y\hat{c}_{t+1} - (g_y - \beta\gamma)(g_y - \gamma)\hat{\Omega}_t - \gamma g_y\hat{z}_t + \beta\gamma g_y\hat{z}_{t+1}$$

First order condition with respect to n_t:

$$\frac{wn}{(1-n)w}\hat{n}_t = \hat{w}_t + \hat{\Omega}_t$$

First order condition with respect to I_t:

$$\hat{\Omega}_t + \hat{\psi}_{it} = \hat{\Theta}_t$$

First order condition with respect to k_t:

$$\hat{\Theta}_t + \hat{z}_{t+1} = \frac{1}{1-\delta+r}(1-\delta)\hat{\Theta}_{t+1} + \frac{1}{1-\delta+r}r\hat{r}_{t+1} + \frac{1}{1-\delta+r}r\hat{\Omega}_{t+1}$$

Other log linearized equations remain the same as the model with steady-state growth, and observables also remain same. The model is estimated using deviation of output growth, consumption growth, and adjusted government expenditure growth from their steady-state values.

A3 Exogeneity test for estimated shocks

Table A1: Regression of cycle shock with other controls (model with cycle shock only, estimated With linearly detrended data)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Shock	Shock	Shock	Shock	Shock	Shock	Shock	Shock
Young dependency ratio	0.00193**							
	(0.012)							
Old dependency ratio		–0.0147***						
		(0.000)						
Terms of trade			–0.000696					
			(0.228)					
Trade to GDP				–0.000495				
				(0.284)				
Broad money to GDP					–0.00111**			
					(0.021)			
Credit to GDP						–0.00156***		
						(0.000)		
FDI to GDP							0.00288	
							(0.169)	
Real rate								–0.0000153
								(0.994)
R^2	0.003	0.010	0.001	0.000	0.003	0.010	0.001	0.000
Observations	2,491	2,491	1,323	2,486	1,771	1,978	2,182	1,093

Note: *, **, and *** denotes significance at 10, 5, and 1 per cent, respectively.

Source: authors' calculations.

Table A2: Regression of cycle shock with other controls (model with cycle shock only, estimated with HP filtered data)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Shock	Shock	Shock	Shock	Shock	Shock	Shock	Shock
Young dependency ratio	0.000178							
	(0.789)							
Old dependency ratio		0.000929						
		(0.721)						
Terms of trade			0.000238					
			(0.640)					
Trade to GDP				0.000961**				
				(0.016)				
Broad money to GDP					–0.000667			
					(0.117)			
Credit to GDP						–0.000799**		
						(0.011)		
FDI to GDP							0.00529***	
							(0.004)	
Real rate								–0.00110
								(0.508)
R^2	0.000	0.000	0.000	0.002	0.001	0.003	0.004	0.000
Observations	2,491	2,491	1,323	2,486	1,771	1,978	2,182	1,093

Note: all items are in local currency. *, **, and *** denotes significance at 10, 5, and 1 per cent, respectively.

Source: authors' calculations.

Table A3: Regression of trend shock with other controls (model with trend shock only)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Shock	Shock	Shock	Shock	Shock	Shock	Shock	Shock
Young dependency ratio	0.0162**							
	(0.044)							
Old dependency ratio		–0.116***						
		(0.000)						
Terms of trade			–0.00652					
			(0.275)					
Trade to GDP				–0.00357				
				(0.459)				
Broad money to GDP					–0.0113**			
					(0.034)			
Credit to GDP						–0.0145***		
						(0.000)		
FDI to GDP							0.0287	
							(0.198)	
Real rate								0.0161
								(0.424)
R^2	0.002	0.006	0.001	0.000	0.003	0.007	0.001	0.001
Observations	2,444	2444	1,323	2,440	1,744	1,949	2,163	1,089

Note: *, **, and *** denotes significance at 10, 5 and 1 per cent respectively.

Source: authors' compilation based on data.

Table A4: Regression of trend shock with other controls

	(1) Shock	(2) Shock	(3) Shock	(4) Shock	(5) Shock	(6) Shock	(7) Shock	(8) Shock
Young dependency ratio	0.00865							
	(0.124)							
Old dependency ratio		–0.0182						
		(0.407)						
Terms of trade			–0.00501					
			(0.204)					
Trade to GDP				0.000750				
				(0.823)				
Broad money to GDP					–0.00827**			
					(0.034)			
Credit to GDP						–0.00955***		
						(0.001)		
FDI to GDP							0.0167	
							(0.282)	
Real rate								–0.0125
								(0.404)
R^2	0.001	0.000	0.001	0.000	0.003	0.006	0.001	0.001
Observations	2,444	2,444	1,323	2,440	1,744	1,949	2,163	1,089

Note: *, **, and *** denotes significance at 10, 5 and 1 per cent respectively.

Source: authors' compilation based on data.

Table A5: Regression of cycle shock with other controls

	(1) Shock	(2) Shock	(3) Shock	(4) Shock	(5) Shock	(6) Shock	(7) Shock	(8) Shock
Young dependency ratio	0.00233							
	(0.613)							
Old dependency ratio		–0.00924						
		(0.608)						
Terms of trade			0.000993					
			(0.779)					
Trade to GDP				0.00147				
				(0.595)				
Broad money to GDP					–0.00173			
					(0.548)			
Credit to GDP						–0.00372*		
						(0.086)		
FDI to GDP							0.0225*	
							(0.080)	
Real rate								0.0292***
								(0.006)
R^2	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.007
Observations	2,444	2,444	1,323	2,440	1,744	1,949	2,163	1,089

Note: *, **, and *** denotes significance at 10, 5, and 1 per cent, respectively.

Source: authors' calculations.

Table A6: Regression of trend shock with habit with other controls

	(1) Shock	(2) Shock	(3) Shock	(4) Shock	(5) Shock	(6) Shock	(7) Shock	(8) Shock
Young dependency ratio	0.00606							
	(0.344)							
Old dependency ratio		–0.0189						
		(0.449)						
Terms of trade			–0.0106**					
			(0.027)					
Trade to GDP				–0.00234				
				(0.541)				
Broad money to GDP					–0.00237			
					(0.613)			
Credit to GDP						–0.00568*		
						(0.091)		
FDI to GDP							0.0183	
							(0.297)	
Real rate								–0.0147
								(0.335)
R^2	0.000	0.000	0.004	0.000	0.000	0.002	0.001	0.001
Observations	2,444	2,444	1,323	2,440	1,744	1,949	2,163	1,089

Note: *, **, and *** denotes significance at 10, 5, and 1 per cent, respectively.

Source: authors' calculations.

Table A7: Regression of cycle shock with habit with other controls

	(1) Shock	(2) Shock	(3) Shock	(4) Shock	(5) Shock	(6) Shock	(7) Shock	(8) Shock
Young dependency ratio	0.0102							
	(0.307)							
Old dependency ratio		–0.0915**						
		(0.019)						
Terms of trade			0.00829					
			(0.277)					
Trade to GDP				0.00426				
				(0.475)				
Broad money to GDP					–0.0110			
					(0.112)			
Credit to GDP						–0.0112**		
						(0.026)		
FDI to GDP							0.00696	
							(0.801)	
Real rate								0.00246
								(0.922)
R^2	0.000	0.002	0.001	0.000	0.001	0.003	0.000	0.000
Observations	2,444	2,444	1,323	2,440	1,744	1,949	2,163	1,089

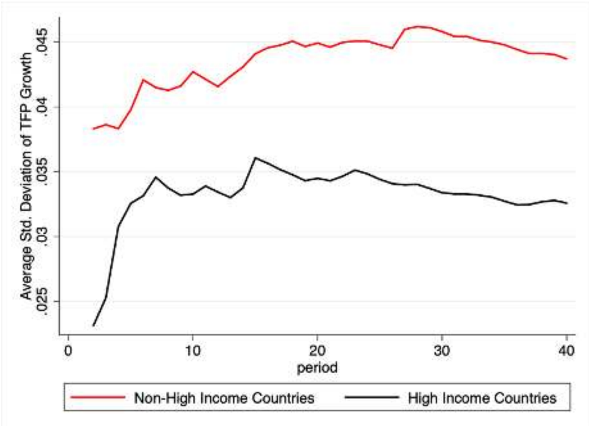
Note: *, **, and *** denotes significance at 10, 5, and 1 per cent, respectively.

Source: authors' calculations.

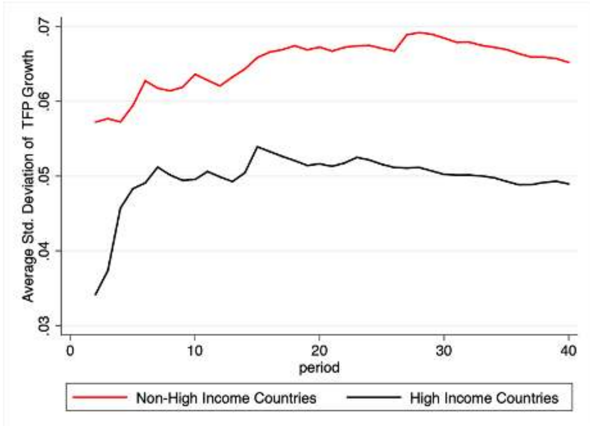
A4 From the data

Figure A4: Average standard deviation of TFP growth using Hicks-neutral productivity in high- and non-high-income countries

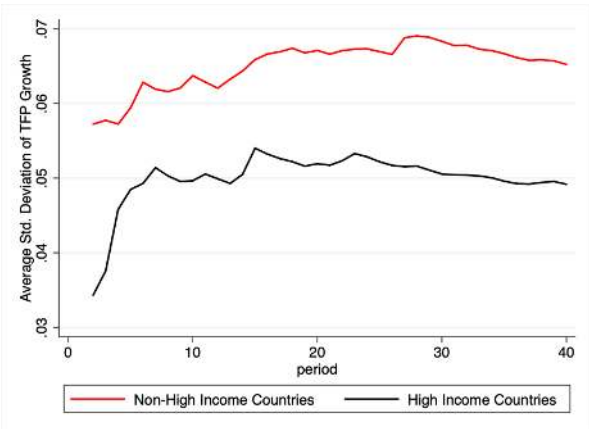
(a)



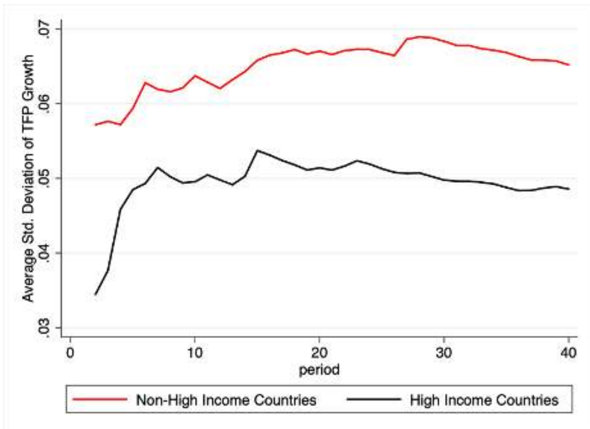
(b)



(c)



(d)

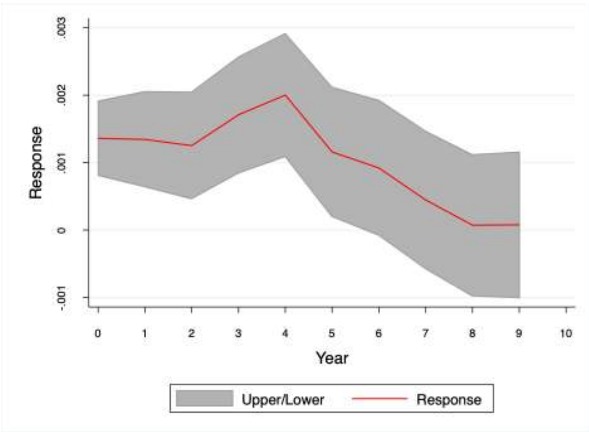


Note: (a) is for baseline-level accounting corrected for difference in labour force participation. (b)–(d) are based on level accounting in Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999), where (b) is for average years of schooling for the population aged 15+, (c) is for average years of schooling for the population aged 25+, and (d) is for average years of schooling corrected for differences in labour force participation.

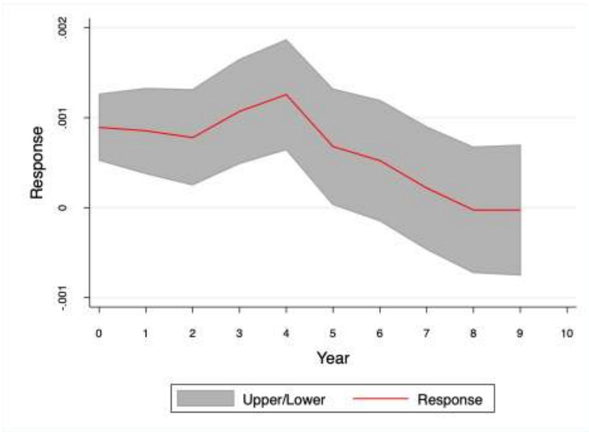
Source: authors' construction.

Figure A5: Response of the saving ratio due to TFP growth using Hicks-neutral productivity from local projections

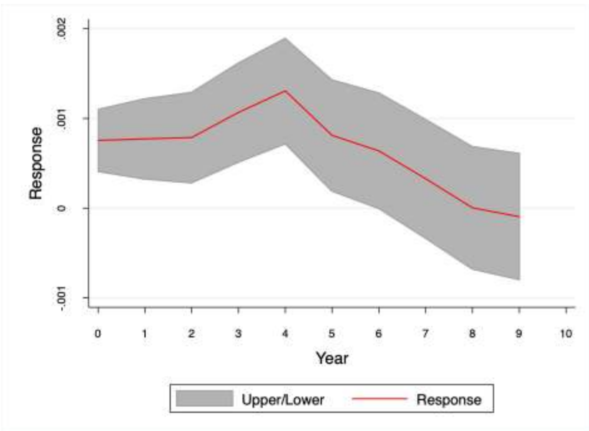
(a)



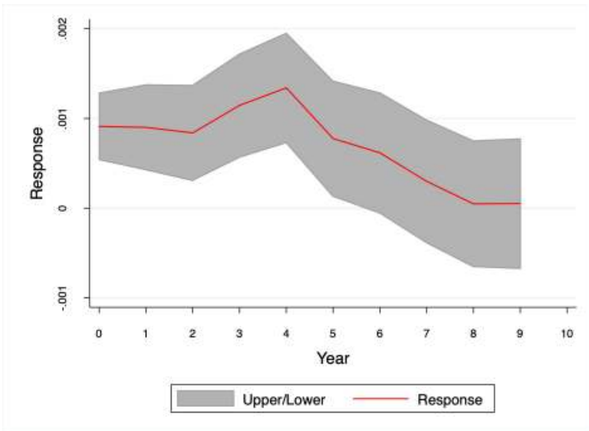
(b)



(c)



(d)



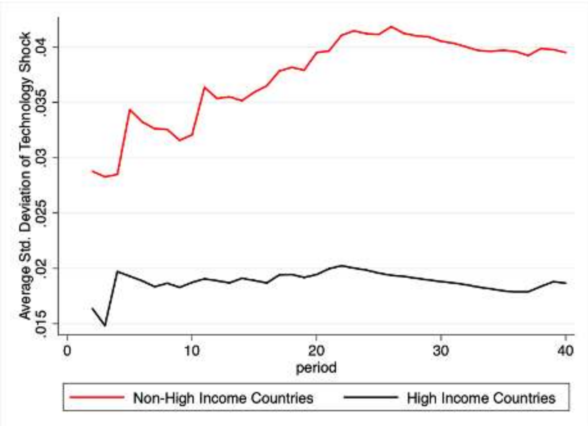
Note: (a) is for baseline-level accounting corrected for difference in labour force participation. (b)–(d) are based on level accounting in Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999), where (b) is for average years of schooling for the populations aged 15+, (c) is for average years of schooling for the populations aged 25+, and (d) is for average years of schooling corrected for differences in labour force participation.

Source: authors' construction.

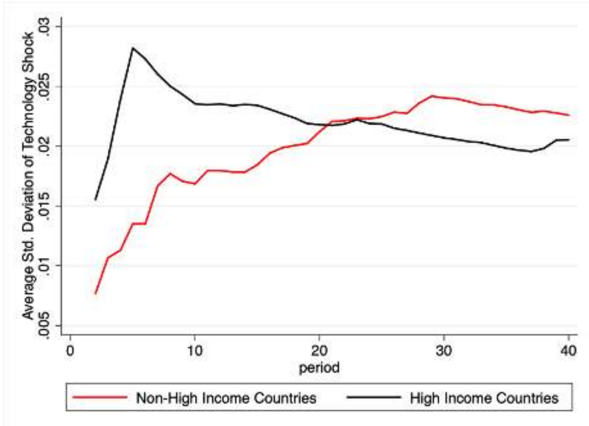
A5 From the model

Figure A6: Average standard deviation of model technology shock in high- and non-high-income countries

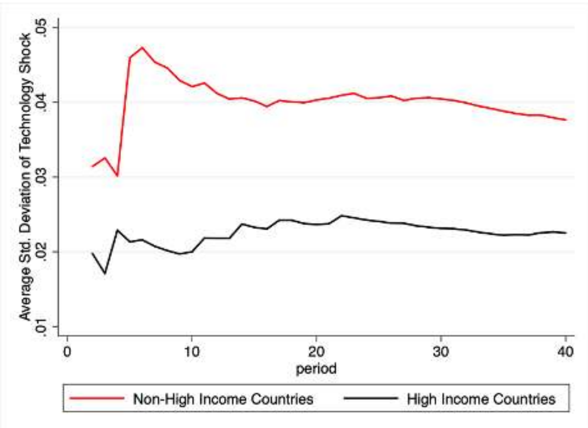
(a) Trend shock



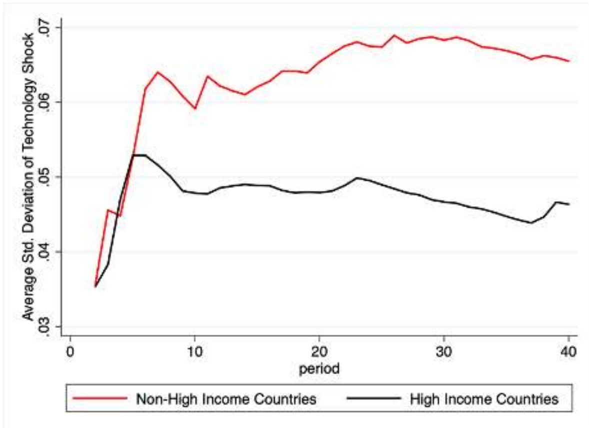
(b) Cycle shock



(c) Trend shock with habit



(d) Cycle shock with habit



Source: authors' construction.