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Fiscal Policy and the Slowdown in Trend Growth in an Open Economy*

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Abstract

We study the impact that a permanent slowdown in trend growth has on fiscal policy with an estimated small open economy model. The magnitude and timing of the change in trend growth are estimated alongside the structural and fiscal policy rule parameters. Around 2003:Q3, trend growth in per capita output is estimated to have fallen from just over 2 per cent to 0.6 per cent annually. The slowdown sets off an endogenous response of the private sector which increases capital accumulation acting as an automatic stabilizer. The slowdown also brings about a lasting transition which in the short-run decreases consumption tax revenues but increases them in the long-run changing permanently the composition of tax revenues and temporarily increasing the government debt to output ratio.

JEL Classification: E30, F43, H30

Keywords: Open economy, trend growth, fiscal policy, real business cycles, estimation, structural breaks.

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1 Introduction

It is becoming increasingly clear that over the past decade or so the growth rate of output per capita in advanced economies has slowed down. The unexpected slow pace of recovery following the global financial crisis – reflected in weak growth rates of investment, consumption, real wages, and productivity – has led to downward revisions of the growth forecasts of policymakers and professional forecasters.[1]

As Figure 1 shows, the recent slowdown has been felt not only in the United States but also in many advanced small open economies, such as Australia, Canada, New Zealand, Norway, Sweden and the United Kingdom. Against this background, we study what the implications of a global slowdown – a slowdown at home and abroad – are for a fiscal authority in a small open economy. We do so with an estimated model of the Australian economy, but as Figure 1 shows, our results will be of interest for small open economies more generally.

In spite of the fact that to date – abstracting from the COVID 19 recession – the Australian economy has experienced the longest economic expansion on record[2], Australia's economic performance since the global financial crisis has deteriorated: output per capita grew on average at 1 per cent per year over the past decade, compared to almost 2.5 per cent per year on average prior to the global financial crisis (Figure 1). Despite the extraordinary boost in the terms of trade, per capita output growth remained lower during the mining boom of 2003-2014 than during the mid 1980s and 1990s, a time when commodity prices were relatively flat. Although the recent deterioration of 2014-2016 in Australia's terms of trade is likely to have contributed to weaker growth outcomes, the low frequency movements in the data suggest that the slowdown in trend growth goes beyond higher frequency fluctuations in the terms of trade.[3]

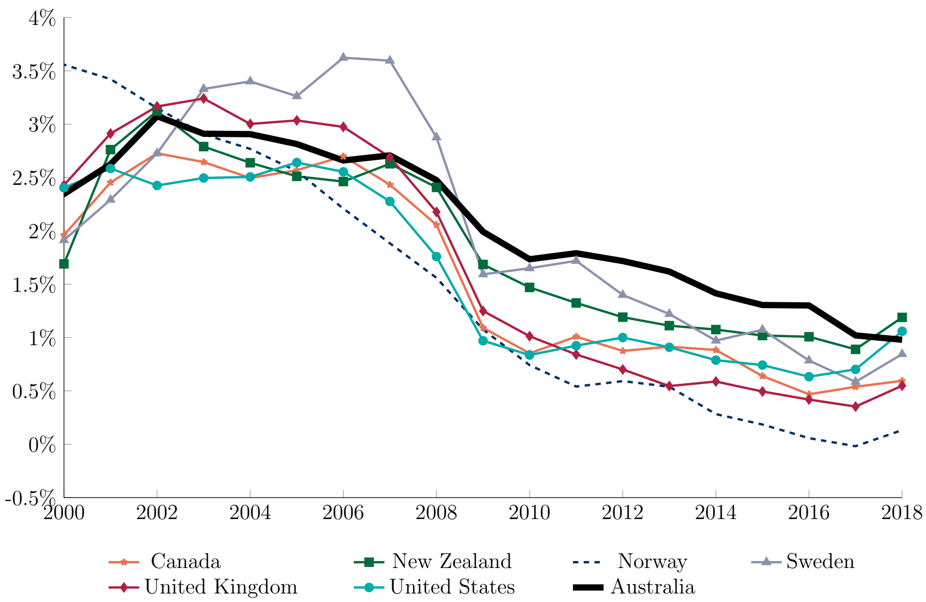
Our work is connected to three strands of the literature. One strand assesses empirically

[1] In its analysis, the International Monetary Fund projects potential growth in advanced economies to average 1.6 per cent per year over the period 2015-2020, well below the pre-crisis average of 2.25 per cent during the period 2001-2007 (IMF, 2015).

[2] See https://www.economist.com/leaders/2018/10/27/what-the-world-can-learn-from-australia.

[3] It is worth noting that the productivity slowdown observed in measures of total factor productivity started around 2003-2004. See 5260.0.55.002 - Estimates of Industry Multifactor Productivity at this link.

Figure 1: Average GDP per capita growth over the past decade:
% per year



Sources: Authors' calculations; FRED

the slowdown in U.S. trend growth: Antolin-Diaz et al. (2016) use a dynamic factor model to document a decline in U.S. trend growth; McCririck and Rees (2016) use a business cycle model that abstracts from fiscal policy and find breaks in productivity growth; and Eo and Morley (2020) using a Markov-switching statistical model detect a reduction in trend growth that began in 2006. Another strand revisits the secular stagnation hypothesis of Hansen (1939): prominent examples are Summers (2015) who argues in support of a demand-side interpretation while Cowen (2011) and Gordon (2015) emphasise lower productivity growth as the cause of the recent slowdown; Jones (2018) shows that an aging population gives rise to a transition with persistently lower productivity growth and studies the implications for monetary policy of a lower real interest rate and a more frequently binding zero lower bound; Eggertsson and Mehrotra (2014) propose an illustrative open economy model to show that a secular stagnation triggered by an oversupply of savings can be eliminated by fiscal stimulus in an open economy. Another strand of the literature, Straub and Coenen (2005), Forni et al. (2009), Leeper et al. (2010) and Ratto et al. (2009), estimate fiscal policy rules to measure the effects of fiscal policy with fully specified structural models.

This paper is different. Our main contribution is to estimate, with aggregate data and a structural model, the magnitude and timing of the slowdown in trend growth in order to understand the quantitative implications for fiscal policy, that is, for government debt, government spending and tax revenues. We use a variant of the canonical small open economy stochastic growth model that we extend to include a fiscal authority that levies lump-sum transfers, as well as taxes on labour income, capital income and consumption expenditures in order to fund interest payments on accumulated government liabilities and general government expenditures. Consistent with a growth accounting exercise which shows that the bulk of the slowdown can be attributed to slowing total factor productivity, the cause of a permanent slowdown in our model is a permanent fall in the growth rate of labour-augmenting technology.[4]

We estimate the permanent change in trend growth together with the model's structural and fiscal policy rule parameters. We find that trend growth in GDP per capita started to fall around 2003 from just over 2 per cent towards our current estimate of just above 0.6 per cent per year. To validate this result, we also estimate an unobserved components model on the GDP per capita series alone, and find a slowdown of a similar magnitude, with trend growth estimated to have fallen to around 1 per cent per year. Thus, the result that there is slowdown in growth is robust. The estimated slowdown from the unobserved components model falls within the posterior distribution of the estimated slowdown from our structural model.

The estimated model is used to quantify and analyse how the slowdown affects the economy and the fiscal position. One may think that a slowdown in trend growth will necessarily deteriorate the fiscal position. This would be the case if government expenditures were to keep growing at the old faster rate but tax revenues were to grow at the new slower rate. Then an ever-growing fiscal imbalance would lead to unsustainable debt dynamics. But the response of fiscal policy to a slowdown in trend growth is different in the model. The model uncovers that the market response to the slowdown acts as an automatic stabilizer and is a key determinant of the transition. Because the slowdown

[4]See the Online Appendix for details about the growth accounting calculations for Australia. Our Online Appendix can be found at https://sites.google.com/site/marianokulish/home/research.

is global, both foreign and domestic real interest rates fall. Consistent with the data, the domestic real interest rate stays above the foreign real interest rate for most of the transition which leads to a deterioration of the current account. Initially, the slowdown reduces consumption as households lower their estimate of permanent income. But it also increases investment, which is partly funded by foreign savings chasing higher relative returns. As consumption falls, so do consumption tax revenues which deteriorates the primary deficit and increases the government debt to output ratio. But the increase in capital accumulation eventually increases tax bases and helps restore fiscal balance. For instance, the real wage increases in the long-run as the additional capital pushes up the marginal product of labour.

The slowdown raises the more general issue of understanding the economy's response in the context of changing policies as well as the ability of a given fiscal policy framework to withstand changes in regime. That fiscal policy rules have evolved over time is clear from the discussion of Pappa (2021) for Europe. The case of a slowing economy, however, makes clear that fiscal rules cast in growth rates are dangerous as they can become inconsistent with a stable equilibrium in the presence of regime change. In Section 5 we discuss and quantify the implications in full, including the importance of assumptions regarding the size of government in the presence of a changing balanced growth path and decomposing the response of the primary surplus to output ratio.

We use the method of Kulish and Pagan (2017) in estimation to allow for, but not to impose, a break in the growth rate of labour-augmenting productivity. As such, the likelihood function is free to choose what change in trend growth, if any, best fits the data. This strategy is also used by Kulish and Rees (2017) to estimate changes in the long-run level of the terms of trade. Aguiar and Gopinath (2007) use consumption and net exports to identify the contributions of permanent and transitory shocks to the level of productivity, but they do not consider permanent changes to the growth rate as we do. Permanent shocks to productivity have a permanent effect on the level of output, but only a transitory effect on the growth rate of output. Our model also has permanent shocks to productivity, but we allow for a break in trend growth. Like these papers, we rely on many observables to achieve identification: real GDP per capita growth, real private consumption per capita growth, net exports to GDP, government spending to GDP, a measure of the domestic real interest rate, a measure of the foreign real interest rate, real wage growth, government debt to GDP, consumption tax revenue to GDP, labour income tax revenue to GDP and capital income tax revenue to GDP.

In Section 2 we develop intuition with the standard neoclassical model to understand the economic forces that are triggered when trend growth permanently falls. We then discuss two plausible assumptions regarding the fiscal policy response to the slowdown that we take to the data with the small open economy model that is set up in Section 3. Section 4 discusses our empirical approach and presents the data. Section 5 describes the main results and in Section 6 we conclude proposing avenues for further research.

2 Trend Growth in the Neoclassical Model

It is useful to build intuition for the empirical exercise that follows by first considering a slowdown in trend growth in the textbook closed economy Ramsey-Cass-Koopmans model (Ramsey (1928), Cass (1965) and Koopmans (1963)). The continuous time neoclassical growth model is well-known, so we restrict our attention to those equations needed to convey our point.[5] As we discuss below, the main result in the closed economy case carries over to the open economy case as well.

Output is produced according to $Y = K^{\alpha}(ZL)^{1-\alpha}$, where Z captures labour augmenting technology which grows at the rate $z = \dot{Z}/Z$, K is the capital stock and L is labour taken to be inelastically supplied and normalised to unity. Lower case letters denote variables in units of effective labour. The representative household preferences expressed in consumption per effective labour are given by:

$$U = \int_0^{\infty} e^{-(\rho-(1-\sigma)z)t} u(c) dt$$

where $u(c) = \frac{c^{1-\sigma}-1}{1-\sigma}$ and ρ is the subjective discount rate.[6] The competitive equilibrium yields paths for consumption and the capital stock that solve the system of differential

[5]See Acemoglu (2008) for a comprehensive discussion of the neoclassical growth model.

[6]For the household's problem to have a well-defined solution it must be that $\rho > (1-\sigma)z$.

equations below.

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}\left[\alpha k^{\alpha-1} - \rho - \delta - \sigma z\right] \tag{1}$$

$$\dot{k} = k^{\alpha} - (z+\delta)k - c \tag{2}$$

Along the balanced growth path, $\dot{c} = \dot{k} = 0$, and consumption and capital are given by:

$$\bar{k} = \left(\frac{\alpha}{\rho + \delta + \sigma z}\right)^{\frac{1}{1-\alpha}} \tag{3}$$

$$\bar{c} = \bar{k}^{\alpha} - (z+\delta)\bar{k} \tag{4}$$

A slowdown in trend growth corresponds to a reduction in the growth rate of labour-augmenting technology, that is, a fall in z. The fall in trend growth results in a permanently higher steady-state level of capital, as implied by Equation (3). In other words, $\frac{\partial \bar{k}}{\partial z} < 0$. Using Equation (3) in (4) it may be shown that

$$\frac{\partial \bar{c}}{\partial z} = [\rho - (1-\sigma)z]\frac{\partial \bar{k}}{\partial z} - \bar{k} = \frac{[-\sigma(\rho - (1-\sigma)z) - (1-\alpha)(\rho + \delta + \sigma z)]}{(1-\alpha)(\rho + \delta + \sigma z)} k < 0$$

and so consumption per unit of effective labour also increases following the fall in trend growth.

Figure 2 shows transitional dynamics in the $k - c$ plane. The economy is initially on its balanced growth path represented by point A. The fall in trend growth shifts the $\dot{c} = 0$ locus to the right and the $\dot{k} = 0$ locus upwards. When trend growth declines, consumption falls to point E putting the economy on its new stable saddle path. Thereafter, c and k rise gradually towards their new steady-state values represented by point B.

As variables are shown in units of effective labour, their evolution does not coincide with the evolution of the levels. Once on the new balanced growth path, point B, the levels of consumption and capital grow at a slower rate even though consumption and capital per unit of effective labour are now higher. This is analogous to what is obtained in the Solow model in response to a fall in the growth rate of the population; slower population growth implies that the levels eventually grow at a slower rate even though per capita quantities are higher in the new balanced growth path.

The fall in trend growth gives rise to income and substitution effects. The fall in z lowers permanent income as real wages are expected to grow at a slower rate. As a result, consumption on impact falls. The fall in consumption increases saving which adds to the capital stock. But the fall in z implies a substitution effect through its impact on the real interest rate, the rate of return on capital net of depreciation. In steady state, Equation (1) implies that the rate of return on capital net of depreciation, $r = f'(k) - \delta$, equals the household's discount rate adjusted by trend growth, $\rho + \sigma z$. On impact, however, the fall in z acts as an increase in the real interest rate, it implies that the net rate of return on capital is above its steady state value, giving households the incentive to reduce consumption today and increase it in the future. As capital accumulates in the transition, its marginal product, $f'(k)$, gradually falls bringing the real interest rate, r, back in line with $\rho + \sigma z$. In the new balanced growth, the capital per unit of effective labour is higher as is output and consumption per unit of effective labour, but the levels, of course, grow at a slower rate.

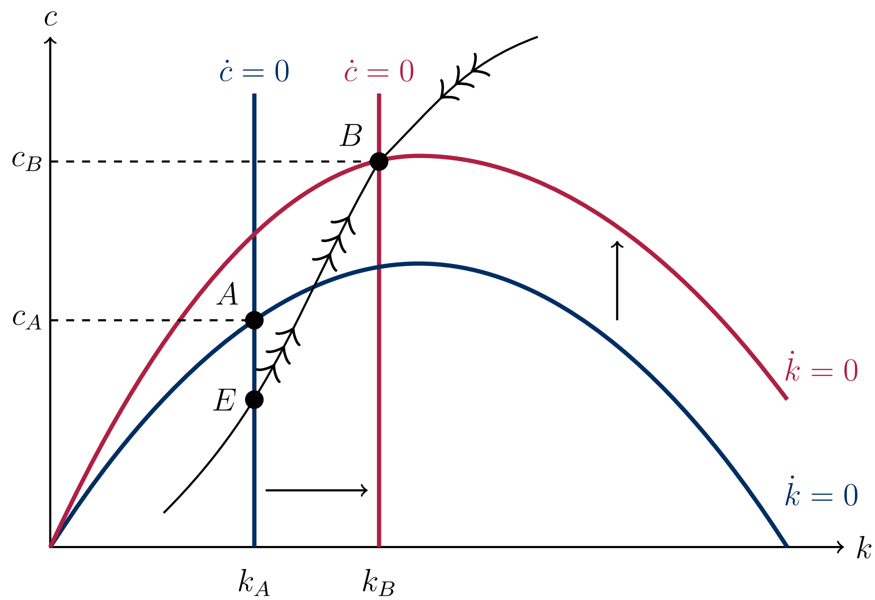
The slowdown in trend growth gives rise to an endogenous response which favors the accumulation of inputs, in this case, of capital. As we will show below when we introduce fiscal policy, this endogenous accumulation of capital in response to the slowdown acts as an automatic stabilizer because it increases the tax base.

Next, we introduce a government sector that spends on goods and services and levies lump-sum taxes. The government maintains a balanced budget so

$$g = \tau \tag{5}$$

where g is government spending and τ are lump-sum taxes both expressed in terms of effective labour units. The competitive equilibrium with fiscal policy yields the paths for consumption and the capital stock that solve Equation (1) and the modified version of

Figure 2: Fall in Trend Growth in the Neoclassical Model



Equation (2) shown below:

$$\dot{k} = k^{\alpha} - (z + \delta)k - c - g \tag{6}$$

Along the balanced growth path, the steady-state capital per unit of effective labour continues to be $\bar{k}$ as per Equation (3). Output is therefore the same as in the case without fiscal policy, but consumption is crowded out as households must pay taxes to finance government consumption.

A fall in z leads to similar responses as before: it increases $\bar{k}$ and $\bar{y} = f(\bar{k})$. However, the impact on consumption depends on how fiscal policy is thought to be pinned down in steady state. We consider the following two cases which we take to the data below. The first, assumes government spending is set so that in steady state the government spending to output ratio is γ, that is

$$g = \gamma\bar{y} \tag{7}$$

In this case the slowdown in trend growth leads to an endogenous increase in $\bar{k}$ and $\bar{y}$ which acts as an automatic stabilizer as it increases the tax base, $\tau = \gamma\bar{y}$.

The second case assumes the government maintains some fixed level of government spending per unit of effective labour, so that

$$g = \tilde{g} \tag{8}$$

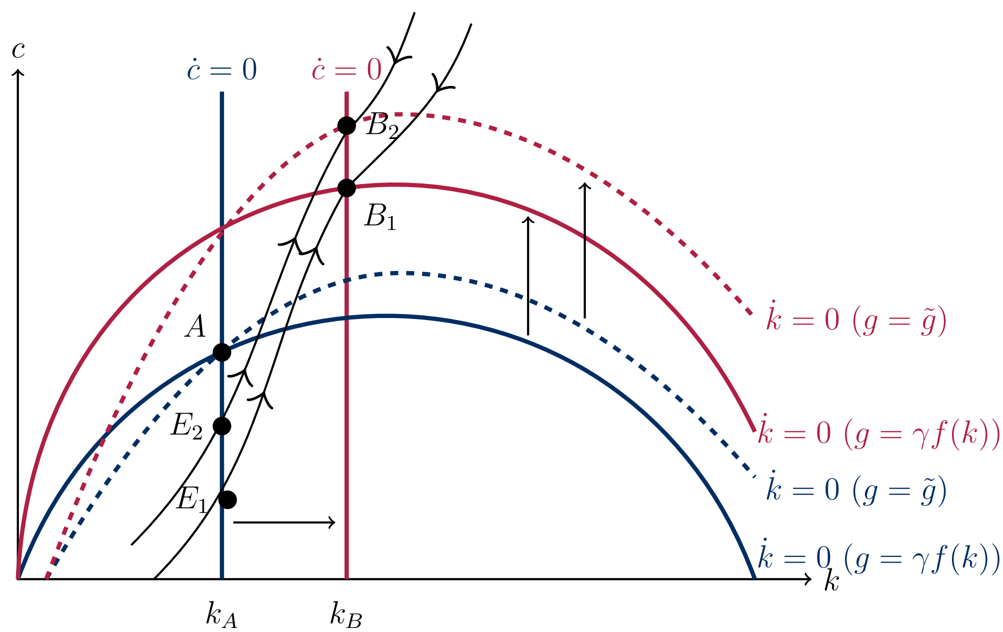
A fall in z increases $\bar{k}$ and $\bar{y} = f(\bar{k})$ by the same amount in both cases. But when the government follows Equation (7), the fall in z leads to an increase in g so that the size of government in the final steady state stays at γ. In the transition, the size of government would exceed γ because Equation (7) implies that g increases as the new steady state is known, although the economy takes time to get there. In the second case, when the government follows Equation (8), the fall in z increases $\bar{y}$ as before but has no impact on g which stays at $\tilde{g}$. In this case the size of government permanently shrinks below γ following the fall in trend growth.

Figure 3 compares the transitional dynamics following a fall in z when the government follows Equation (7) with those obtained when the government follows Equation (8). In the initial steady state, at point A, we set $\tilde{g}$ so that it equals $\gamma\bar{y}$. This explains why the two $\dot{k} = 0$ curves pass through point A. When z falls, consumption falls in both cases following the intuition above. But consumption falls by less when the government follows Equation (8) reflecting that relatively less taxes are required as the size of government shrinks in the transition towards the new steady state. In the new steady state, of course, the consumption to output ratio is higher under Equation (8) than under Equation (7).

To extend this analysis to an open economy, one must specify if the slowdown in trend growth is solely a domestic phenomenon or a global one instead. This assumption is important because it has implications for the dynamics of real interest rate differentials between the domestic economy and the rest of the world and consequently for the evolution of net foreign assets and the trade balance. Because the data strongly suggests that the slowdown is global (Figure 1), we consider the case in which there is a common rate of trend growth at home and abroad. As trend growth declines permanently, consumption falls as in the closed economy case and domestic and foreign real interest rates eventually converge to a common lower level although a real interest rate spread arises temporarily in the transition.

In the next section, we set up an empirically plausible small open economy stochastic growth model with government debt, lump-sum taxes as well as distortionary taxes on consumption, labour and capital income, habits in consumption and shocks to preferences, technologies and fiscal instruments. In that model, however, the way government spending responds to the change in trend growth determines transitional dynamics and the long-run properties of the economy in terms of the consumption to output and the government spending to output ratios in the same way as we discussed above.

Figure 3: Fall in Trend Growth with Fiscal Policy



3 A Small Open Economy Model

Next, we set up a small open economy stochastic growth model along the lines of Uribe and Schmitt-Grohé (2017) for the empirical application that follows.

3.1 Households and Firms

The representative household maximises expected lifetime utility given by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \zeta_t \left(\frac{(C_t - hC_{t-1})^{1-\sigma} - 1}{1-\sigma} - \zeta_t^L Z_t^{1-\sigma} \frac{L_t^{1+\nu}}{1+\nu} \right) \tag{9}$$

subject to the period budget constraint:

$$(1+\tau_t^c)C_t + I_t + B_t + B_t^F \leq R_{t-1}B_{t-1} + R_{t-1}^F B_{t-1}^F + (1-\tau_t^w)W_t L_t + (1-\tau_t^K)r_t^K K_{t-1} + TR_t$$

and the capital accumulation equation:

$$K_t = (1-\delta)\,K_{t-1} + \zeta_t^I\left[1 - \Upsilon\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{10}$$

In the equations above, C_t is consumption, τ_t^c is the tax rate on consumption, I_t is investment, B_t stands for government bonds and R_t for its gross rate of return, B_t^F stands for foreign bonds and R_t^F for its gross rate of return, L_t are hours worked, W_t is the real wage per hour worked and τ_t^w is the tax rate on labour income. The capital stock available for production at time t is K_{t-1} and r_t^K is its rental rate, while τ_t^K is the tax rate on capital income. TR_t stands for lump sum taxes or transfers. The parameter $h \in [0,1]$ is the habit formation coefficient, $1/\sigma$ is the intertemporal elasticity of substitution and $1/\nu$ is the Frisch elasticity. ζ_t is an intertemporal preference shock that follows:

$$\ln \zeta_t = \rho_\zeta \ln \zeta_{t-1} + \varepsilon_{\zeta,t} \tag{11}$$

and ζ_t^L is a labour supply shock that follows:

$$\ln \zeta_t^L = \rho_L \ln \zeta_{t-1}^L + \varepsilon_{L,t} \tag{12}$$

ζ_t^I is a shock to the marginal efficiency of investment which is assumed to follow:

$$\ln \zeta_t^I = \rho_I \ln \zeta_{t-1}^I + \varepsilon_{I,t} \tag{13}$$

The function that governs the investment adjustment cost satisfies, $\Upsilon(z) = \Upsilon'(z) = 0$ and $\Upsilon'' > 0$.

Output is produced with a Cobb-Douglas production function by competitive firms hiring capital and labour:

$$Y_t = K_{t-1}^{\alpha}\,(Z_t L_t)^{1-\alpha} \tag{14}$$

where Z_t is labour-augmenting technology whose growth rate, $z_t = Z_t/Z_{t-1}$, follows:

$$\ln z_t = (1-\rho_z)\ln z + \rho_z \ln z_{t-1} + \varepsilon_{z,t} \tag{15}$$

and so z governs the growth rate of labour-augmenting TFP along the balanced growth path. The term $Z_t^{1-\sigma}$ in Equation (9) ensures, as explained by King et al. (1988), that hours worked do not grow or shrink along the balanced growth path.

In steady state it can be shown that the real interest rate is related to productivity growth by the expression below

$$R = \frac{z^\sigma}{\beta}$$

Thus, σ can be thought to determine the extent to which permanent changes in productivity growth translate into permanent changes in the real interest rate. Relative to log utility, this specification gives the model additional flexibility as permanent changes in z are not restricted to translate one to one into permanent changes in R. The empirical application that follows relies on many observables including real interest rates. Because σ is estimated, the data can determine the degree of pass-through from real interest rates to inferences of trend growth. Below we allow, but do not require, a break in z at some point in the sample from z to $z' = z + \Delta z$. Trend growth in the initial regime, z, is calibrated and Δz estimated.

3.2 Trade Balance and Net Foreign Assets

Following Schmitt-Grohe and Uribe (2003), the interest rate that the household receives on foreign bonds depends on the economy's net foreign asset position according to the debt-elastic interest rule:

$$R_t^F = R_t^* \exp\left[-\psi_b\left(\frac{b_t^F}{y_t} - \frac{b^F}{y}\right) + \zeta_t^b\right] \tag{16}$$

where $\frac{b^F}{y}$ is the steady-state ratio of net foreign assets to output, and ζ_t^b is the country risk premium shock which follows the process below:

$$\zeta_t^b = (1-\rho_b)\zeta^b + \rho_b \zeta_{t-1}^b + \varepsilon_{b,t} \tag{17}$$

and R_t^* is the foreign real interest rate which follows the exogenous process below:

$$\ln R_t^* = (1-\rho_{R^*}) \ln R^* + \rho_{R^*} \ln R_{t-1}^* + \varepsilon_{R^*,t} \tag{18}$$

In steady state, the foreign real interest rate is $R^* = z^\sigma \exp(-\zeta_b)/\beta$. The assumption that the slowdown is global is reflected by the fact that when trend growth falls so will R^*. However, R_t^* will converge gradually, governed by ρ_{R^*}, to its lower steady state. Equation (16) shows that if R_t^F were to exactly track R_t^* then net foreign assets would stay constant. If, however, due to endogenous persistence arising from investment adjustment costs and habits in consumption, R_t^F takes longer to reach its steady state, then the domestic real interest rate would temporarily exceed the foreign real interest rate. A positive real interest rate differential leads to a capital inflow from the rest of the world, a trade deficit and a deterioration in the net foreign asset position. Eventually the trade deficit would recover and restore the steady-state net foreign asset position, b^F/y.

The trade balance is output less domestic absorption, that is,

$$NX_t = Y_t - C_t - I_t - G_t \tag{19}$$

and the current account is therefore given by:

$$CA_t = NX_t + (R_{t-1}^F - 1)B_{t-1}^F \tag{20}$$

In equilibrium, net foreign assets evolve according to:

$$B_t^F = R_{t-1}^F B_{t-1}^F + NX_t \tag{21}$$

The levels of variables, except for hours worked and interest rates, trend at the rate of z. When normalised by Z_t, however, the variables $b_t = B_t/Z_t$, $c_t = C_t/Z_t$, $y_t = Y_t/Z_t$, and so on, converge in the absence of shocks to their steady state values which we denote by b, c, y and so on.

3.3 The Government

The government receives tax payments on consumption, labour and capital income as well as lump-sum taxes and borrows domestically to finance government spending. Thus, the government budget constraint is:

$$B_t + \tau_t^c C_t + \tau_t^w W_t L_t + \tau_t^K r_t^K K_{t-1} + TR_t = R_{t-1} B_{t-1} + G_t \tag{22}$$

We assume the government sets government spending and taxes rates following fiscal rules which include a response to deviations of the government debt to output ratio from its steady state. In particular, we assume rules of the form:

$$\ln g_t = (1-\rho_g)\ln g + \rho_g \ln g_{t-1} - (1-\rho_g)\gamma_{gb}\left(\frac{b_{t-1}}{y_{t-1}} - \frac{b}{y}\right) + \varepsilon_{g,t} \tag{23}$$

$$\tau_t^c = (1-\rho_c)\tau_c + \rho_c \tau_{t-1}^c + (1-\rho_c)\gamma_{cb}\left(\frac{b_{t-1}}{y_{t-1}} - \frac{b}{y}\right) + \varepsilon_{c,t} \tag{24}$$

$$\tau_t^w = (1-\rho_w)\tau_w + \rho_w \tau_{t-1}^w + (1-\rho_w)\gamma_{wb}\left(\frac{b_{t-1}}{y_{t-1}} - \frac{b}{y}\right) + \varepsilon_{w,t} \tag{25}$$

$$\tau_t^K = (1-\rho_K)\tau_K + \rho_K \tau_{t-1}^K + (1-\rho_K)\gamma_{Kb}\left(\frac{b_{t-1}}{y_{t-1}} - \frac{b}{y}\right) + \varepsilon_{K,t} \tag{26}$$

$$\tau_t = (1-\rho_\tau)\tau + \rho_\tau \tau_{t-1} + (1-\rho_\tau)\gamma_{\tau b}\left(\frac{b_{t-1}}{y_{t-1}} - \frac{b}{y}\right) + \varepsilon_{\tau,t} \tag{27}$$

where the normalised variables $\tau_t = \frac{TR_t}{Z_t}$, $y_t = \frac{Y_t}{Z_t}$, $g_t = \frac{G_t}{Z_t}$, $b_t = \frac{B_t}{Z_t}$, have steady states τ, y, g and b respectively. Throughout, τ is set so that given all other fiscal policy rule parameters the government budget constraint, equation (22), holds in steady state.

4 Empirical Analysis

The model in Section 3 is linearised around its non-stochastic steady state and the method of Kulish and Pagan (2017) is used to solve and estimate the model in the presence of structural breaks.

The structural parameters can be categorised as either having only an impact on the dynamics of the model – persistence parameters of shock processes, adjustment costs, fiscal policy rule parameters and standard deviations – or as having, in addition to an impact on the dynamics, an impact on the steady state. Our strategy follows that of Adolfson et al. (2007) and Kulish and Rees (2017) in that we calibrate the parameters that pin down the steady state to match first moments of the data and estimate the first category of parameters together with the consumption habit parameter h, the household discount factor β, the inverse intertemporal elasticity of substitution σ, and the change in the steady-state growth rate between the initial and final steady state Δz.

4.1 Calibration

We set z to 1.0055 in the initial steady state to match GDP per capita growth for the period 1983:Q1 to 2008:Q4. In the final steady state the growth rate is $z' = 1.0055 + \Delta z$, where Δz is estimated. Given z, we jointly estimate β and σ such that in steady state the mean of the domestic real interest rate is 4.2 per cent in annual terms. We set the country risk premium, ζ_b, to match the differential between the sample means of the domestic and the foreign real interest rates. The production function parameter, α, is set to match the mean of the investment and consumption to output ratios. The rate of capital depreciation, δ, is set to match the consumption of fixed capital out of the net capital stock. The government debt to annual GDP ratio is set to match its sample mean of 13 per cent. We set the tax rates on consumption, labour income and capital income so as to match tax revenues from each source as a per cent of GDP. The government spending to output ratio is chosen to correspond to total government spending (consumption plus investment) in the data.[7] Finally, we set the inverse Frisch elasticity of labour supply, ν,

[7] Our choice of observable variables uses the sum of government consumption plus investment to make the model consistent with observed GDP in the data. We leave for future research assessing the

to 2, which is standard in the literature. Table 1 summarises the values of the calibrated parameters.

Table 1: Calibrated Parameters

Parameter	Description	Value
δ	Capital depreciation rate	0.016
ν	Inverse Frisch	2
z	Steady-state TFP growth	1.0055
α	Capital share in production	0.29
b^*	Steady-state net foreign assets	0
g/y	Steady-state government spending to output	0.23
b/y	Steady-state debt to output	0.56
τ^c	Steady-state consumption tax rate	0.06
τ^w	Steady-state labour income tax rate	0.17
τ^K	Steady-state capital income tax rate	0.13
ψ_b	Risk premium sensitivity	0.01
ζ_b	Country risk premium	0.0049

Table 2 evaluates the resulting calibration by comparing model moments with those in the data for the pre-financial crisis sample. We choose to match the moments in the pre-crises sub-sample because in the presence of possible breaks in trend growth, full sample statistics do not reflect any one regime. The calibrated model captures key features of the economy well. There is a small discrepancy in matching net exports, but this is a deliberate choice. In steady state, Equation (21) implies that positive net exports cover interest payments on foreign liabilities, or that interest income on foreign assets fund negative net exports. An issue arises because over our sample period the economy has had a trade deficit and a negative net foreign asset position. Because of this reason we decide to strike a balance and set the net foreign asset position to zero in steady state, which implies balanced trade.

4.2 Estimation

In estimation we follow the literature on estimated dynamic stochastic general equilibrium models.[8] Our case, however, is non-standard because we allow for structural change and

implications of government investment along the lines, for example, proposed by Bouakez et al. (2017).

[8] See An and Schorfheide (2007) for a description of these techniques.

Table 2: Steady State Calibration

Target	Average 1983-2008	Model
Macro Aggregates (annual per cent)		
Per capita output growth	2.2	2.2
Domestic real interest rate	4.2	4.2
Foreign real interest rate	2.3	2.3
Expenditure (per cent of GDP)		
Consumption	57.2	56.1
Investment	20.4	20.3
Government spending	23.6	23.6
Net exports	-1.3	0.0
Tax Revenues (per cent of GDP)		
Consumption tax	3.7	3.7
Labour income tax	12.3	12.3
Capital income tax	4.1	4.1
Borrowing (per cent of annual GDP)		
Government Debt	13.4	13.4

Note: Model ratios calculated at initial regime where $z = 1.0055$.

therefore jointly estimate two sets of distinct parameters: the structural parameters of the model, θ, that have continuous support and the dates of structural changes, $\mathbf{T} = (T_z, T_\sigma)$ that have discrete support; T_z is the date break in the growth rate of labour-augmenting technology and T_σ is the date break in the variance of shocks[9]. To capture the great moderation, the fact that the variance of macroeconomic aggregates has fallen, we use a parsimonious specification and introduce the parameter μ, which multiplies all standard deviations before T_σ, i.e. the standard deviations of all variables are assumed to shift in the same proportion. Both μ and T_σ are then estimated.

The joint posterior density of θ and $\mathbf{T}$ is:

$$P(\theta, \mathbf{T}|\mathbf{Y}) \propto \mathbf{L}(\mathbf{Y}|\theta, \mathbf{T})p(\theta, \mathbf{T}), \tag{28}$$

where, $\mathbf{Y} \equiv \{y_t^{obs}\}_{t=1}^{T}$ is the data and y_t^{obs} is a $n^{obs} \times 1$ vector of observable variables. The likelihood is given by $\mathbf{L}(\mathbf{Y}|\theta, \mathbf{T})$. The prior of the structural parameters and the

[9]See Kulish and Pagan (2017) for the general methodology of solving and estimating models under structural change; the online appendix of Kulish and Rees (2017) discusses an application to a particular case similar to ours.

prior of date breaks are taken to be independent, so that $p(\theta, \mathbf{T}) = p(\theta)p(\mathbf{T})$. We use a flat prior for $\mathbf{T}$ over admissible dates and use trimming so that the earliest possible date for the final regime (low trend growth and variances) is the first quarter of 2002. The trimming ensures that the initial regime (high trend growth and variances) is long enough and avoids incorrectly capturing a break in the early 2000's that may be due to the introduction of the goods and services tax rather than due to a change in trend growth. Kulish and Pagan (2017) discuss how to construct $\mathbf{L}(\mathbf{Y}|\theta, \mathbf{T})$ in models with forward-looking expectations and structural changes as well as how to set up the posterior sampler.

The model is estimated on 10 Australian and 1 foreign quarterly macroeconomic time series for the period 1983:Q1 to 2018:Q1. Real GDP and private consumption are seasonally adjusted and measured in chain volume terms, while government spending[10] and net exports are seasonally adjusted and measured in current prices. Output and consumption are expressed in per capita terms by dividing by the population derived from the GDP per capita series. These series enter in first differences, while government spending and net exports enter as shares of nominal GDP. The sample mean of consumption growth is adjusted prior to estimation and the sample mean of net exports to GDP is removed to align it with the model's steady state. The hourly wage series is derived by dividing the compensation of employees series by the hours worked index. We then deflate the hourly wage by the consumption deflator. The real wage series enters in first differences with its sample mean adjusted to equal the mean of output growth. The domestic interest rate is the 90-day bank bill rate and the foreign interest rate is the U.S. 3-months treasury bill rate. The domestic and foreign nominal interest rates are converted to real rates using the trimmed mean inflation and the US core PCE inflation series, respectively.

The measure of government debt is government securities on issue expressed as a share of nominal GDP. For the tax revenues, we use sales taxes plus goods and services

[10]Our measure of government spending from the national accounts differs from the measure of government spending in the Commonwealth budget papers due to differences in accounting methodologies. The main difference is that government spending reported in the budget papers includes transfer payments, while our quarterly measure from the national accounts corresponds to a measure of public final demand and therefore excludes transfer payments. In our model, net transfers (lump-sum payments less lump-sum receipts) is a residual implied by the government budget constraint (Equation (22)).

taxes as a measure of consumption tax revenues, the tax on individual income series as a measure of labour income tax revenues, and income tax on resident corporations and on non-residents series as a measure of capital income tax revenues. The tax revenues series are expressed as a share of nominal GDP. We adjust the mean of the consumption tax revenues to GDP series for the subsample 1983-2000 to account for the introduction of the goods and services tax in 2000.

4.3 Priors

We choose a uniform prior with a wide support of -0.01 to 0.01 for Δz which corresponds to the parameter of most interest in this analysis. This implies that the estimate for the growth rate in the final regime, z', can range anywhere between 0.9955 and 1.0155, which in annual terms translates to a range of -1.8 to 6.2 per cent.

Other choices follow the literature: Beta distributions for the persistence coefficients and Inverse Gamma distributions for the standard deviations of the shocks. We use a normal prior for σ that is centered at 1, consistent with log utility, and has a standard deviation of 0.2. The household discount factor β is then set to achieve a 4.2 per cent real interest rate annually in the steady state. In the case of the fiscal policy rules response coefficients to the debt to output ratio, we use uniform priors over a range that restricts the coefficients so that each fiscal instrument responds to stabilise debt. This does not imply stability over the prior parameter space; it only shrinks the region of unstable debt dynamics.

5 Results

5.1 Structural Parameters and Date Breaks

The estimates of the structural parameters for our preferred specification are shown in Table 3. Starting with our parameter of most interest, Δz, there is strong evidence in favour of a slowdown in trend growth. Figure 4 shows the posterior distribution of $z' = z + \Delta z$ together with the mean of growth for the period 1983-2008 which is our

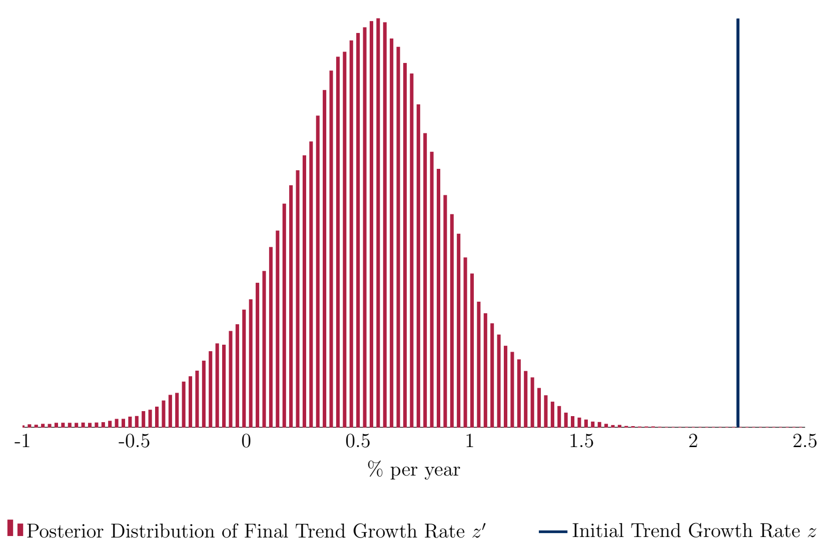
Table 3: Prior and Posterior Distribution of the Structural Parameters

	Prior distribution			Posterior distribution			
Parameter	Distribution	Mean	S.d.	Mean	Mode	5%	95%
Structural Parameters							
h	Beta	0.5	0.25	0.56	0.56	0.48	0.64
σ	Normal	1	0.2	1.00	1.03	0.77	1.25
Υ''	Normal	5.0	2.0	2.13	1.88	1.25	3.23
Δz	Uniform	[-0.01, 0.01]		-0.0041	-0.0040	-0.0057	-0.0026
μ	Uniform	[0, 3]		2.11	2.09	1.84	2.39
γ_{gb}	Uniform	[0, 0.5]		0.12	0.05	0.01	0.35
γ_{cb}	Uniform	[0, 0.5]		0.02	0.01	0.00	0.06
γ_{wb}	Uniform	[0, 0.5]		0.03	0.02	0.00	0.07
γ_{Kb}	Uniform	[0, 0.5]		0.11	0.04	0.01	0.31
$\gamma_{\tau b}$	Uniform	[0, 0.5]		0.05	0.04	0.01	0.10
AR Coefficients							
ρ_z	Beta	0.50	0.19	0.16	0.16	0.07	0.25
ρ_{R^*}	Beta	0.71	0.16	0.81	0.81	0.75	0.86
ρ_ζ	Beta	0.71	0.16	0.95	0.97	0.88	0.99
ρ_L	Beta	0.71	0.16	0.99	0.99	0.99	0.99
ρ_I	Beta	0.50	0.19	0.46	0.49	0.26	0.66
ρ_b	Beta	0.50	0.19	0.52	0.53	0.42	0.61
ρ_g	Beta	0.71	0.16	0.91	0.91	0.84	0.96
ρ_c	Beta	0.71	0.16	0.96	0.96	0.92	0.99
ρ_w	Beta	0.71	0.16	0.87	0.88	0.81	0.93
ρ_K	Beta	0.71	0.16	0.95	0.95	0.91	0.98
ρ_τ	Beta	0.50	0.19	0.24	0.25	0.11	0.38
Standard Deviations							
σ_z	Inv. Gamma	0.01	0.30	0.009	0.009	0.008	0.010
σ_{R^*}	Inv. Gamma	0.01	0.30	0.002	0.002	0.002	0.002
σ_ζ	Inv. Gamma	0.10	0.30	0.025	0.020	0.015	0.047
σ_L	Inv. Gamma	0.10	0.30	0.028	0.028	0.025	0.032
σ_I	Inv. Gamma	0.10	0.30	0.073	0.065	0.041	0.116
σ_b	Inv. Gamma	0.10	0.30	0.003	0.003	0.003	0.003
σ_g	Inv. Gamma	0.10	0.30	0.023	0.023	0.021	0.026
σ_c	Inv. Gamma	0.01	0.30	0.002	0.002	0.001	0.002
σ_w	Inv. Gamma	0.01	0.30	0.007	0.007	0.006	0.007
σ_K	Inv. Gamma	0.01	0.30	0.010	0.009	0.009	0.011
σ_τ	Inv. Gamma	0.10	0.30	0.065	0.064	0.058	0.072
Log marginal likelihood: 5508.3							

calibrated value for trend growth in the initial regime. After the break, trend growth in GDP per capita in annual terms is estimated to be around 0.6% at the mode of the posterior. And while there is some uncertainty around this estimate, there is no mass close to the trend growth rate of the initial regime.

The top panel of Figure 5 shows the estimated cumulative distribution function for the date break in trend growth. The mean for the break in trend growth is estimated to be the third quarter of 2003 while the mode is the second quarter of 2002. There is about 60% probability that the break in trend growth occurred between 2002 and 2003; the remaining 40% probability is spread between 2003 and 2008. Consistent with the finding in Eo and Morley (2020) for the U.S., the break in Australia is also estimated to have taken place prior to the global financial crisis of 2008/09.

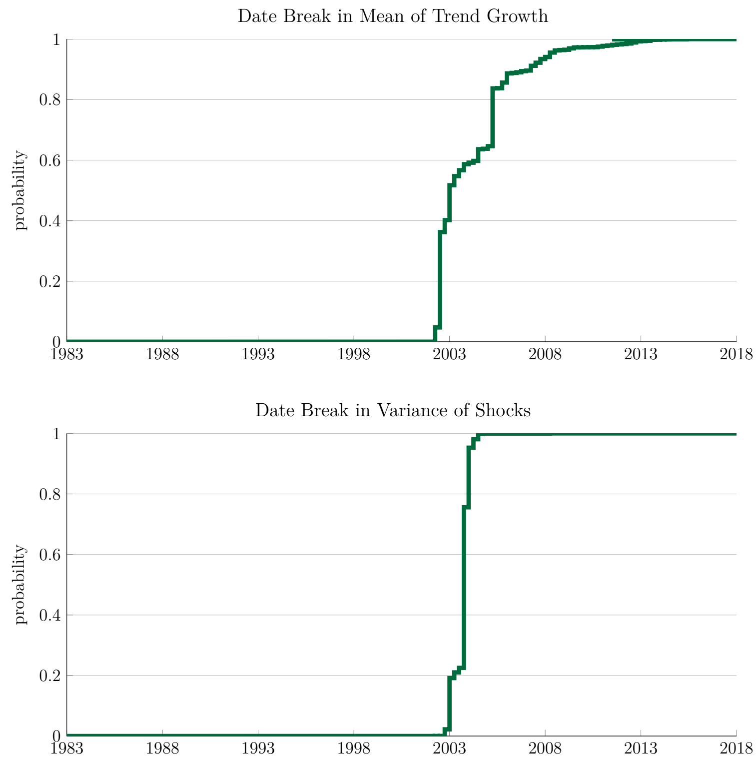
Figure 4: Posterior Distribution of Trend Growth



5.2 Model fit

To assess the fit of the model we compare, for the observables, one-sided one-step ahead predictions from the model against actual outcomes. As can be seen in Figure 6, the model tracks the fluctuations in the data closely for most variables. Wage growth and output growth appear to be exceptions, but these variables are quite volatile at a quarterly frequency, and given their lack of persistence, they are hard to predict. As shown by

Figure 5: Cumulative Posterior Distributions of Date Breaks

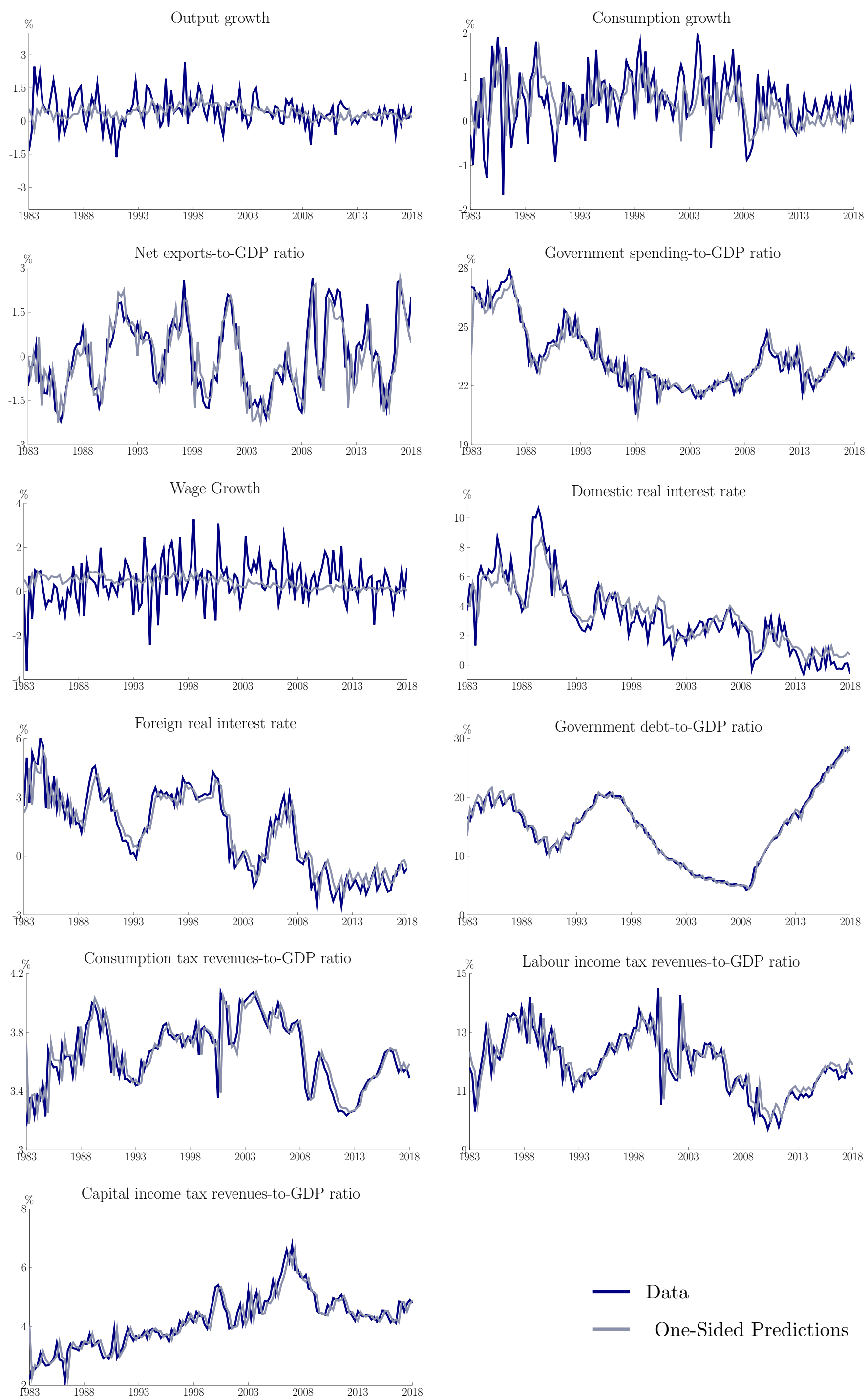


the variance decomposition below, productivity shocks, $\varepsilon_{z,t}$, which have a low estimated persistence, $\rho_z = 0.16$, explain a large fraction of the variance of these variables. Because these series have low persistence, the model actually does a good job relying on non-persistent processes to explain these data, just as the best predictor for a white noise process would simply be its mean. The model does a good job tracking the fiscal policy variables which is an indication that the specification of fiscal policy rules fits the data reasonably well.

5.3 Estimated transitional dynamics

To assess the quantitative implications of the estimated change in trend growth, Δz, we start by computing the transitional dynamics implied by the joint posterior of structural parameters and date breaks. We take 100 draws from the posterior and at each draw compute the non-stochastic transition path: the path that the economy would follow in the absence of structural shocks but in the presence of Δz at time T_z.

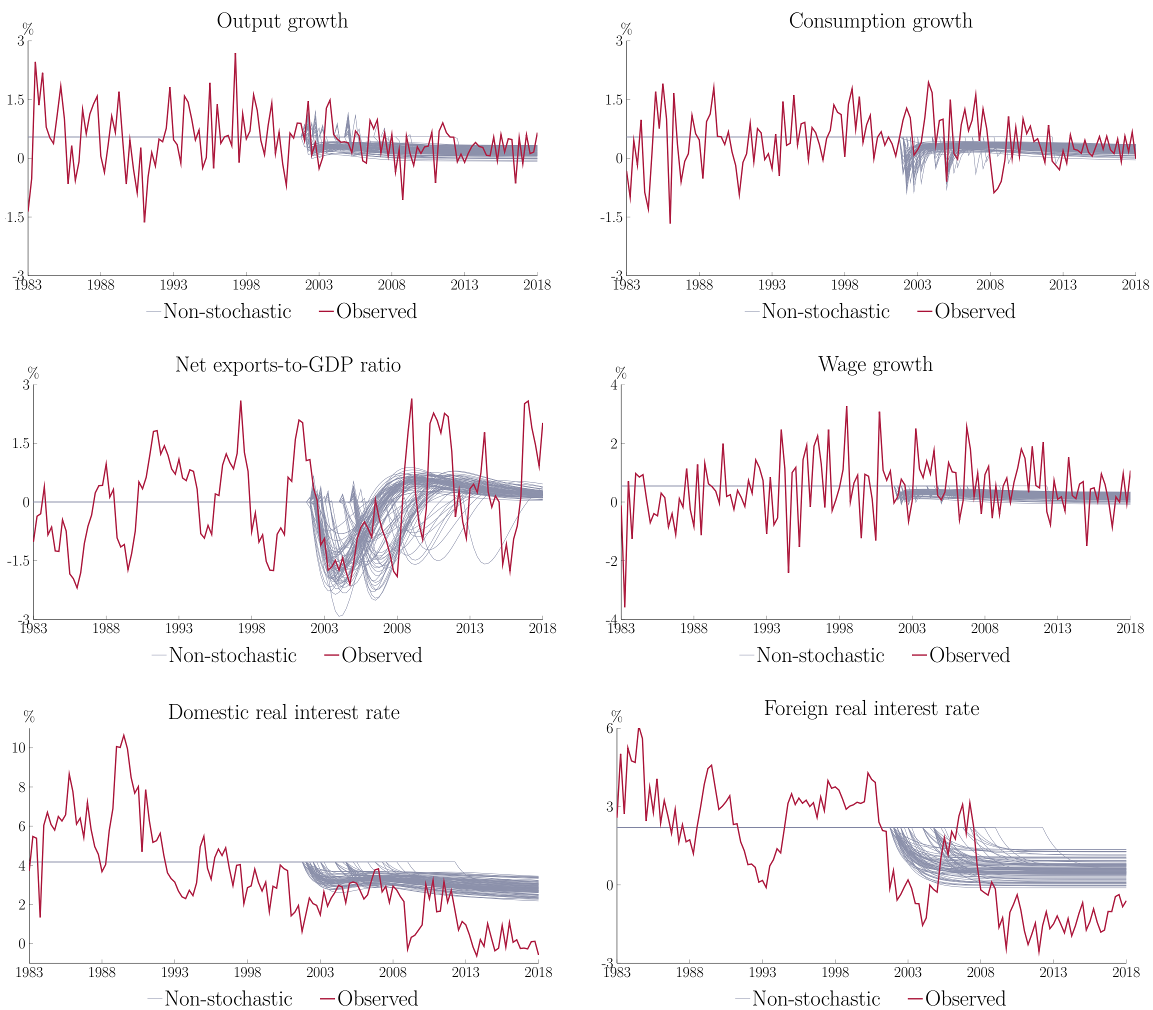
Figure 6: One-Sided Predictions and Data



Sources: ABS; AOFM; Authors' calculations; FRED; RBA

Figures 7a and 7b plot the posterior distribution of the estimated transitional dynamics for the observable variables used in estimation. Most transition paths start around the second quarter of 2002, the mode of the date break in z, although some paths start after that.

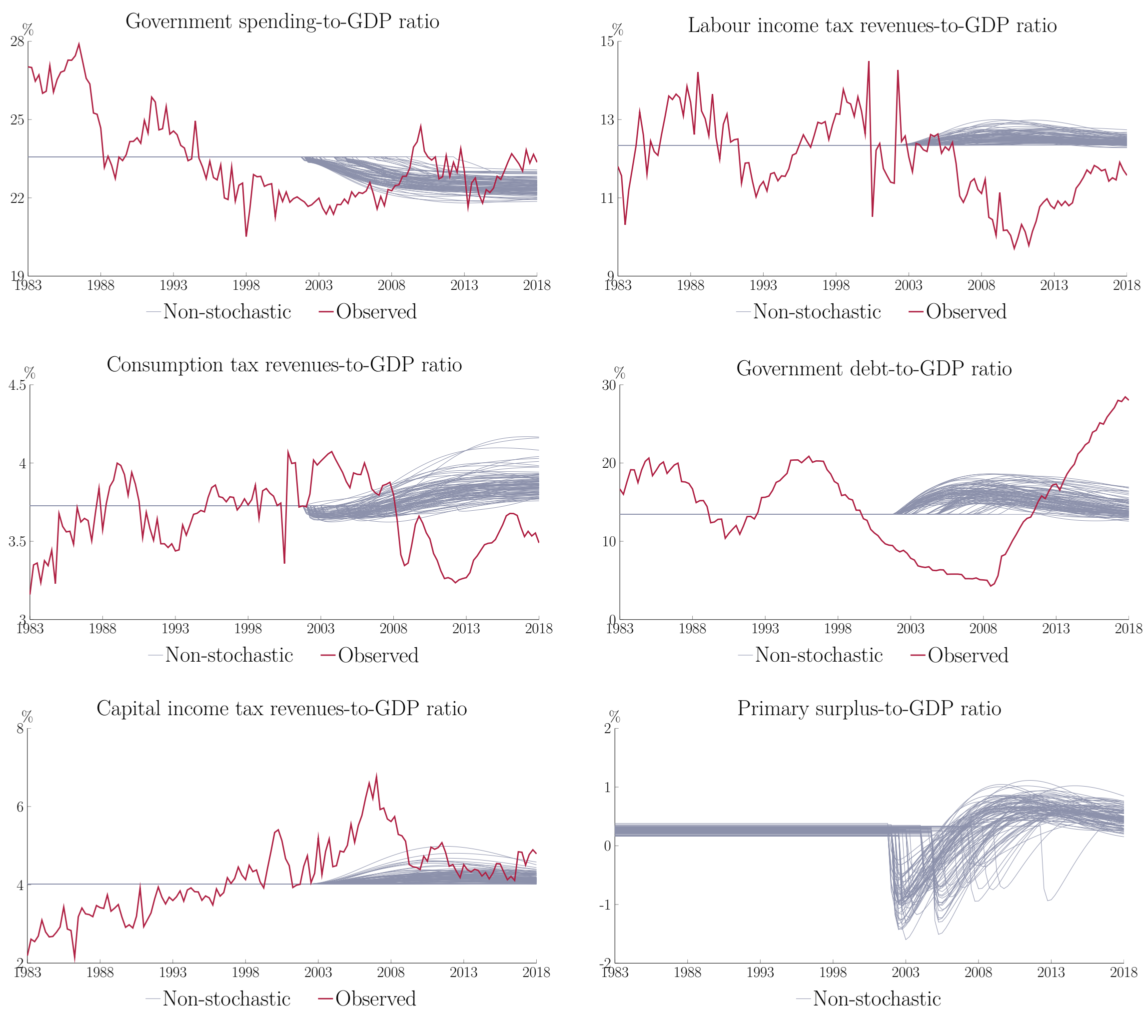
Figure 7a: Data and Estimated Transitional Dynamics



Sources: ABS; Authors' calculations; FRED; RBA

The fall in trend growth gives rise to a long-lasting transition towards a new balanced growth path. As trend growth decreases globally, the foreign real interest rate, R_t^*, gradually converges, at the rate of ρ_{R^*}, towards its new lower steady state. In the initial stages of the transition, however, the foreign real rate, R_t^*, falls below the domestic

Figure 7b: Data and Estimated Transitional Dynamics



Sources: ABS; AOFM; Authors' calculations

real interest rate. The domestic real interest rate, R_t, takes longer to adjust due to the estimated sources of endogenous persistence: habits in consumption, investment adjustment costs, and fiscal policy rule parameters.

A positive interest rate spread, $R_t > R_t^*$, leads to capital inflows reflected in a deterioration of the trade balance as shown in Figure 7a. If the persistence of the foreign real interest rate, ρ_{R^*}, were sufficiently higher, it would take longer for R_t^* to adjust and R_t could therefore fall below R_t^* on the transition. In this case capital will flow out of the domestic economy and the trade balance would consequently improve. Thus, the relative persistence of the domestic real interest rate to the foreign real interest rate is an important determinant of the response of a small open economy to a global slowdown in trend growth. Across the estimated posterior distribution, however, we find that the trade balance deteriorates in the initial stages of the transition and subsequently recovers to restore the net foreign asset position of the economy.[11]

In the baseline specification, the fiscal authority leaves fiscal policy rules unchanged, in particular g in Equation (23). As we explain below, this assumption implies that the government spending to output ratio, g_t/y_t, gradually falls towards its new steady state. At the mean of the posterior, the government spending to output ratio takes around a decade to converge from its initial steady state value of 23.5 per cent to the lower value of 22.1 per cent. We discuss this in detail in the next subsection.

As explained in Section 3, lump-sum transfers adjust to satisfy the government budget constraint in the long-run. When g does not adjust, the g/y ratio fall by 1.4 percentage points. Because the consumption share of output increases in the new balanced growth path, the consumption tax revenue share of output increases by 0.2 percentage points. So for the government budget constraint to hold in the long-run, the lump-sum tax share of output must fall by around 1.6 percentage points. The speed with which lump-sum taxes fall towards the new steady state is governed by ρ_τ, which is estimated at 0.24. The persistence of government spending, ρ_g, is significantly higher, 0.91 at the mode, so government spending as a share of output takes longer than lump-sum taxes to adjust. And although consumption tax revenues eventually increase, the initial fall in consumption depresses consumption tax revenues. As a result of these forces, following the fall in trend growth, the primary deficit initially deteriorates which contributes to a rise in the government debt to output ratio.

Tax rates on capital income, labour income and consumption expenditures subsequently rise in response to rising government debt according to Equations (24) to (26) helping to restore fiscal balance. The increase in the tax rate on capital income together with the increase of the capital stock fueled by the rise of investment more than offsets the fall

[11]The spread, $R_t - R_t^*$, is mildly negative in the first quarter of the transition which explains why there is an increase in net exports on impact.

in interest rates and so tax revenues from capital income increase as share of output in the transition; eventually, it converges back to $\tau^K \left(\frac{r^K K}{Y}\right) = \tau^K \alpha$ which in the long-run is independent of z. The increase in the capital stock increases the marginal product of labour which increases real wages. Hours worked on impact increase as consumption falls and as a result tax revenues from labour income also rise as share of output in the transition; but eventually, this share converges back to $\tau_w(1-\alpha)$, which also does not depend on z.

5.4 Decomposing the fiscal response to the slowdown

As we discuss above, a permanent change in trend growth permanently changes the balanced growth path and implies a transition towards it. This subsection first discusses how the steady state government budget constraint is affected by trend growth, z, and then decomposes the response of tax revenues and government spending into direct (or exogenous) and indirect (or endogenous) components along the transition path implied by the fall in z.

5.4.1 The steady state government budget constraint

In steady state, the government budget constraint, Equation (22), expressed in terms of shares of output becomes:

$$\frac{g}{y} + \left(\frac{1}{\beta} - 1\right)\frac{b}{y} = \tau_c \frac{c}{y} + \tau_w(1-\alpha) + \tau_K \alpha + \frac{\tau}{y} \qquad (29)$$

where we have used the fact that for our production function the labour share of income is $1-\alpha$ and the capital share of income is α. In the absence of any permanent tax reforms, a permanent decrease in trend growth, from z to the lower value of z', has no impact on the long-run values of the tax revenue shares of output from labour and capital income: the term $\tau_w(1-\alpha) + \tau_K\alpha$ does not depend on z. But as argued in Section 2, the consumption share of output, c/y, increases in the new balanced growth path. If the government spending to output ratio, g/y, and the government debt to output ratio, b/y were to remain constant across steady states then lump-sum transfers to output must fall to offset the increase in the consumption tax revenue, $\tau_c c/y$, for the government budget constraint to be satisfied in the long-run.

In the empirical application, a permanent fall in z leads to an increase in the steady state value of detrended output from y to y' as is the case in Section 2. Whether the government spending share of output remains the same depends on whether the fiscal authority updates its fiscal policy rule parameter g in Equation (23). If the fiscal authority recognises the regime change when it happens, the constant in Equation (23), g, increases to say g' so that in the new balanced growth path the government spending share of output is back to the same value, that is $g/y = g'/y'$. During the transition, the increase to g' implies a gradual increase in government spending according to Equation (23). If the fiscal authority does not adjust g in Equation (23) when the change in trend growth happens, the government spending to output ratio gradually decreases in the transition towards a lower value, g/y'. In both cases, lump-sum transfers are assumed to adjust to satisfy the government budget constraint in the long-run. We take both hypotheses regarding the adjustment of g to the data and find that the specification in which the government spending to output ratio gradually decreases fits the data better. We therefore take the case in which g remains constant in Equation (23) as our baseline specification.

Whether the government spending to output ratio remains the same or falls in the new steady state, the level of government spending, $G_t = g_t Z_t$, in the new steady state will eventually grow at the lower rate of trend growth. Thus one can think of g, the steady state of g_t, as pinning down the level, while the growth rate of government spending in the long-run is pinned down by the growth rate of Z_t, and is independent of g, the constant in equation (23). Thus, whether the government updates g or not, a rule like (23) captures the proposal of Darvas et al. (2019) according to which expenditures do not grow faster than income. But notice that the case in which the fiscal authority does not update g, implies a transition in which income grows temporarily faster than government expenditures which is their recommendation for high debt countries.

Consider instead a case in which fiscal policy specifies a rule but for the *growth rate* of government spending. Imagine that the fiscal authority were not to update its government spending rule when trend growth falls. Such a rule would, of course, lead to explosive debt dynamics and be inconsistent with the existence of a stable equilibrium and a balanced growth path. Restricting the analysis to rules that are consistent with the existence of a balanced growth path then implies that in the long-run, a slowdown in trend growth will eventually slowdown the growth rates of government spending and of tax revenues. But the exact way in which this will take place depends not only on exogenous productivity, Z_t, but also on the endogenous responses of public and private sectors.

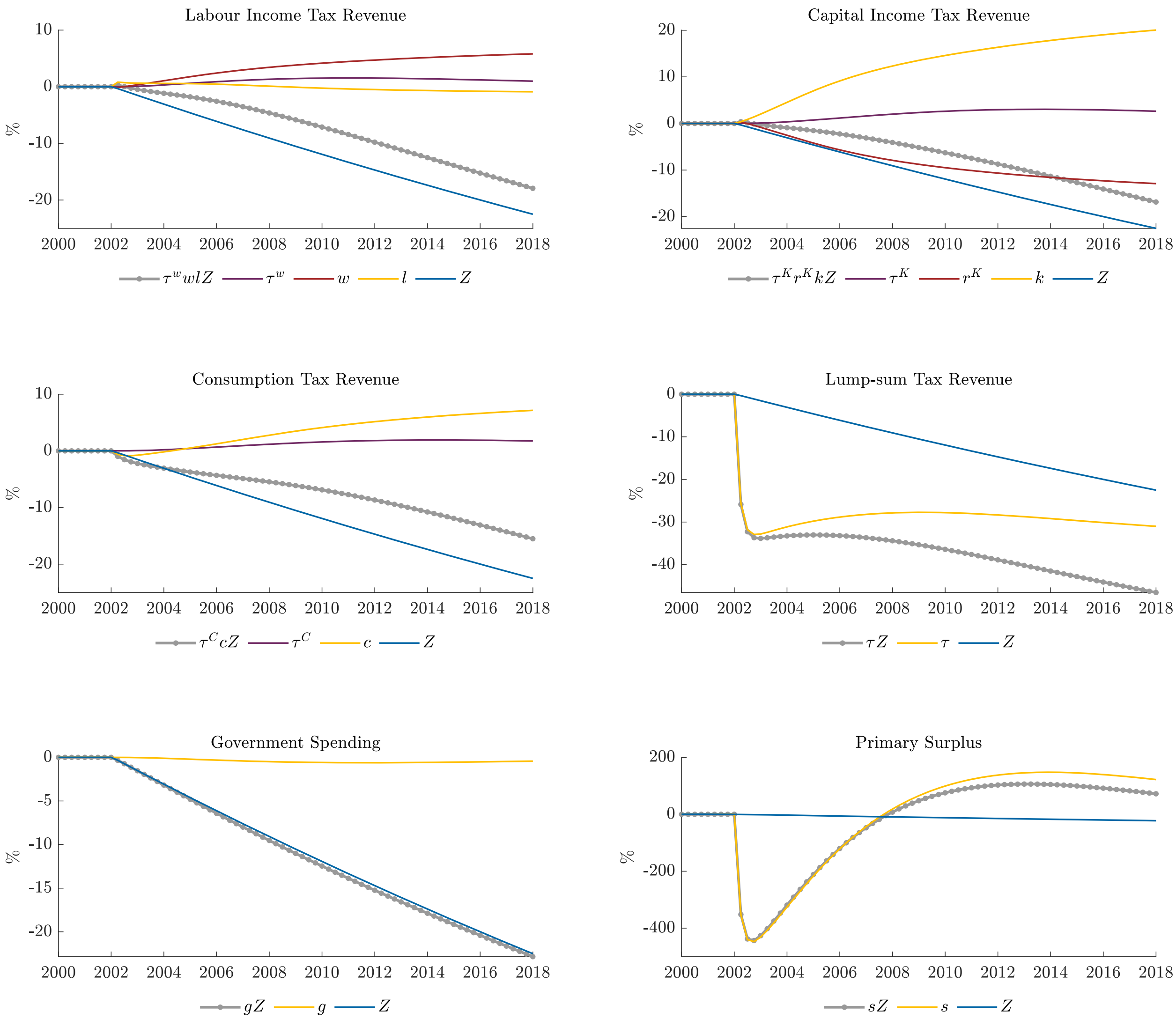
Next, we turn to decomposing the response of fiscal policy into direct and indirect effects.

5.4.2 Exogenous and endogenous responses of fiscal policy

In the case of the level government spending, $G_t = g_t Z_t$, we can think of Z_t as governing the purely exogenous component or the direct effect of the slowdown, while g_t, captures the indirect effect as it responds endogenously according to (23). Tax revenues from the various sources can also be decomposed into direct and indirect effects. Take the case of tax revenues from labour income which can be written as $\tau_t^w w_t Z_t L_t$ using the fact that $w_t = W_t/Z_t$. In this case there is also a direct effect coming from the slowdown in productivity, Z_t, and indirect effects coming from the endogenous responses of the labour market, w_t and L_t, and from the way fiscal policy adjusts tax rates on labour income, τ_t^w, according to (25). Tax revenues from capital income, $\tau_t^K k_t Z_t r_t^K$, can be decomposed in a similar way as is the case with other sources of tax revenue.

Figure 8 decomposes the responses of spending and tax revenues into exogenous and endogenous components and plots the deviation from the counterfactual path of no-break in trend growth. This decomposition is done at the estimated mode of the parameter values. As one would expected the direct effects of the slowdown are significant. The direct effect dominates the response of government spending, with government spending accumulating around a negative 20% deviation from the no-slowdown path towards the end of the sample. The responses of labour income and capital income tax revenues show, however, quite significant indirect effects. When trend growth falls, households reassess future income and respond by cutting consumption and increasing labour supply. This in turn, increases capital accumulation which boosts the marginal product of labour and

Figure 8: Decomposing the fiscal response



Note: percentage deviation of the non-stochastic path with a slowdown from the non-stochastic path without a slowdown.

decreases the return on capital. Other lump-sum transfers fall rapidly in line with (27) which together with a fall in consumption tax revenues open up a primary deficit. The increase in tax rates as result of the increasing debt to output ratio, together with a strong response of capital accumulation, consumption and wages help to buffer the slowdown in tax revenues and eventually give rise to a reversion towards a primary surplus. As the primary surplus recovers, the debt to output ratio is stabilised and the economy gradually converges to its new balanced growth path.

Up to this point we have analysed the impact of change in z in the absence of shocks. Next, we assess the implications of the slowdown in trend growth for the impact of shocks by looking at variance decompositions.

5.5 Variance Decompositions

In our sample, the economy can be in one of four possible regimes. The estimated cumulative distribution functions, however, suggest that the most prevalent are the high trend growth high variance and the low trend growth low variance regimes. Table 4 computes variance decompositions of the two regimes for the observable series used in estimation.

In spite of the estimated regime changes, the contributions of shocks to the variance of the observables is broadly stable across regimes. Productivity and labour supply shocks account for over 80 per cent of the variance of output growth. Fiscal policy shocks, shocks to government spending and tax revenues, however, do not account for the bulk of the fluctuations in output growth, consumption growth, net exports, wage growth and the domestic real interest rates which suggests that fiscal policy is not a significant source of macroeconomic volatility.

5.6 Sensitivity Analysis

Next we analyse the extent to which the estimate of Δz is sensitive to the choice of observable variables. To assess this we consider the distance between the observable series and their estimated transitional dynamics; this distance is due to structural shocks. As can be seen in Figures 7a and 7b, many observable series are closer to their estimated transitional dynamics which implies that smaller shocks are required to fit these observables under a slowdown in trend growth. This observation points to which observables are relevant for identifying Δz and also suggests that an estimation that fails to account for a break in z will fit these data series worse. In fact, we have estimated the model without breaks and found that the log marginal density falls from 5508.3 to 5480.8 which is evidence in favor of a specification that allows for a permanent change in trend growth.

Table 4: Variance Decompositions

	Shock										
Variable	ε_z	ε_{R^*}	ε_ζ	ε_L	ε_I	ε_b	ε_g	ε_c	ε_w	ε_K	ε_τ
Initial Regime											
Output growth	42.5	3.7	5.5	37.0	2.2	3.7	0.7	0.0	4.6	0.1	0.0
Consumption growth	22.9	7.1	28.5	30.8	2.6	3.9	2.5	0.4	0.7	0.4	0.0
Net exports/GDP	3.3	15.7	6.0	4.2	60.2	3.5	4.7	0.0	0.8	1.5	0.0
Wage growth	79.7	1.0	2.5	12.0	2.0	1.1	0.2	0.0	1.5	0.1	0.0
Domestic real interest rate	1.4	30.3	5.9	1.1	5.5	54.7	0.5	0.0	0.1	0.5	0.0
Foreign real interest rate	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Government spending/GDP	0.6	0.1	2.1	75.8	0.7	0.0	20.1	0.0	0.3	0.4	0.1
Government debt/GDP	0.3	0.1	1.8	71.0	0.2	0.0	11.3	0.8	3.8	5.5	5.2
Consumption tax revenues/GDP	1.4	0.5	7.8	24.6	1.0	0.2	5.1	50.4	2.6	3.8	2.6
Labour income tax revenues/GDP	0.1	0.0	0.7	29.6	0.1	0.0	4.2	0.3	61.3	2.1	1.6
Capital income tax revenues/GDP	0.1	0.0	0.6	25.7	0.1	0.0	2.7	0.2	0.8	68.8	1.0
Final Regime											
Output growth	42.1	3.6	6.1	37.7	1.7	3.6	0.5	0.0	4.6	0.1	0.0
Consumption growth	22.2	7.0	32.2	28.0	3.2	3.9	2.0	0.5	0.7	0.4	0.0
Net exports/GDP	3.3	16.3	6.9	4.5	58.9	3.6	4.4	0.0	0.8	1.2	0.0
Wage growth	79.5	1.0	2.7	12.4	1.5	1.1	0.1	0.0	1.5	0.1	0.0
Domestic real interest rate	1.3	30.6	5.2	1.1	5.6	55.2	0.4	0.0	0.1	0.4	0.0
Foreign real interest rate	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Government spending/GDP	0.6	0.1	2.3	75.8	0.6	0.0	19.9	0.0	0.3	0.4	0.1
Government debt/GDP	0.4	0.1	2.0	72.8	0.2	0.0	9.9	0.9	3.7	5.5	4.5
Consumption tax revenues/GDP	1.5	0.4	8.8	28.9	1.0	0.2	4.4	46.6	2.5	3.7	2.2
Labour income tax revenues/GDP	0.2	0.0	0.8	31.2	0.1	0.0	3.8	0.3	60.0	2.2	1.5
Capital income tax revenues/GDP	0.1	0.0	0.7	27.3	0.0	0.0	2.5	0.2	0.8	67.4	0.9

Note: The variance shares are reported in per cent.

To study the sensitivity of the estimate of Δz to the set of observables, we first estimate an unobserved components model on the GDP per capita series alone, allowing for a change in trend growth and a change in the variance of shocks as we did with the structural model.[12] The key result from this exercise is a mode of $z' = z + \Delta z$ at 1.0029 which corresponds to an annual rate of trend growth of 1.16%. The date break is estimated to have taken place in 2008:Q1. The estimate of z' is higher in the unobserved

[12]In the interest of space, we relegate the details of this exercise as well as results from the Markov-switching specification of Eo and Morley (2020) to the Online Appendix.

components model than the estimate of z' in the structural model of 0.6% per year, but the posterior distributions of Δz overlap to a large extent as evident in Figure 9. We also cast the unobserved components model in growth terms and estimate the first-difference specification using GDP per capita growth as an observable. We find that the estimated change in trend growth and date breaks are virtually unaffected in comparison with the estimates obtained using the level of GDP per capita as the observable variable.

Figure 9: Posterior Distribution of Trend Growth

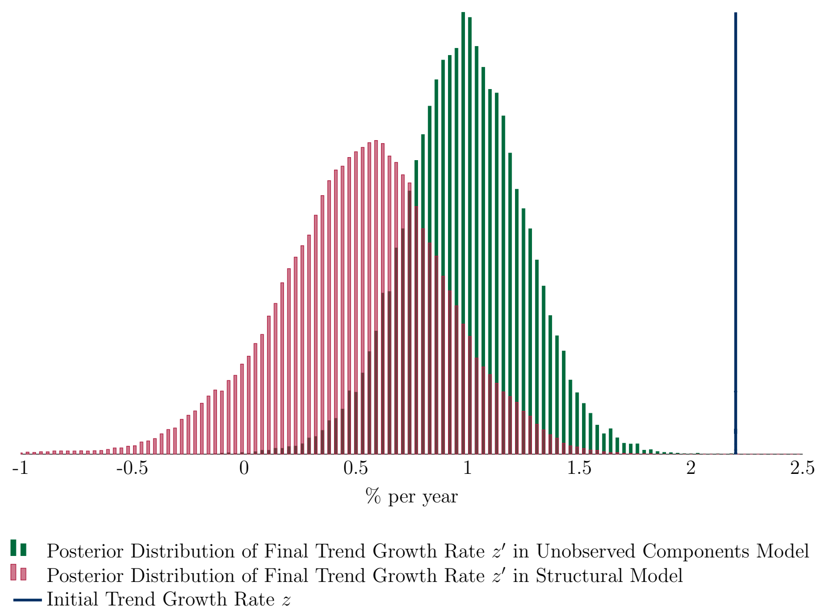
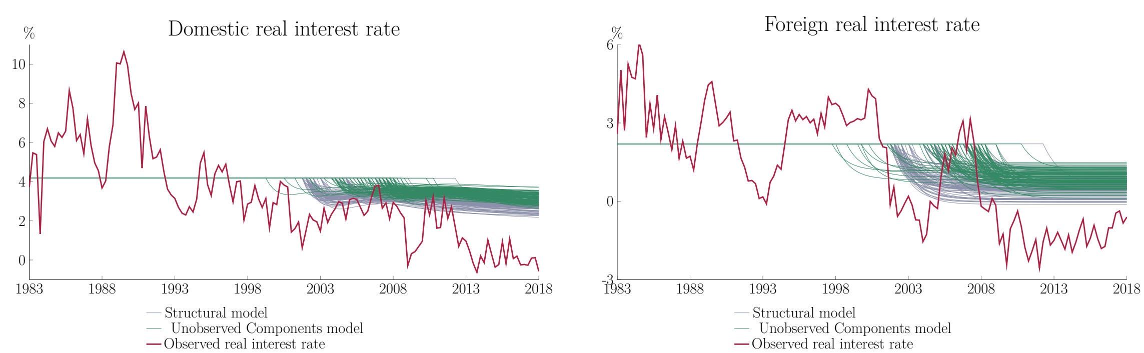


Figure 10: Estimated Transitional Dynamics:
Real Interest Rates



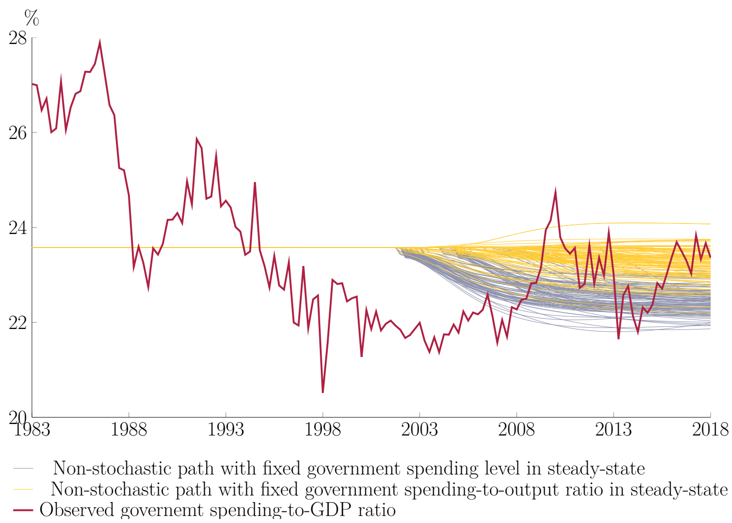
Sources: Authors' calculations; FRED; RBA

In a series of estimations, we then remove one observable series at a time to assess how the mode of $z' = z + \Delta z$ changes. The government spending to output ratio, net exports to output ratio and the domestic and the foreign real interest rates all contribute to the somewhat lower estimate of z'. In particular, when the domestic and the foreign real interest rates are removed from the list of observables, we find the estimate of trend growth rises at the mode from 0.6% to 1.4% in the final regime; the mode of 1.4% for z' falls within the posterior distribution of the baseline specification. When the government spending to output ratio is removed, the estimate of trend growth rises to 1.47%; when the net exports to GDP ratio is removed the estimate of trend growth is 0.8%. Figure 10 compares transitional dynamics of the domestic and foreign real interest rates implied by the posterior distribution from the unobserved components model with the posterior distribution from the structural model. As can be seen in the figure, the lower estimate of Δz helps the structural model fit the domestic and foreign real interest rate series better.

Apart from differences in the point estimates and the uncertainty surrounding them, all estimations point to a slowdown in trend growth. In fact, although we believe real interest rates contain information about long-run productivity growth, a slowdown in trend growth would still be detected if real interest rates were removed from the set of observables. In other words, a permanent slowdown in trend growth does not rest on real interest rates. This is important because it demonstrates that the recent low levels of real interest rates brought about by factors other than slower productivity growth are not decisive drivers of our main inferences. Our result that in the neoclassical growth model a slowdown in trend growth lowers real interest rates is also consistent with the findings in Holston et al. (2017) and Del Negro et al. (2019) that show that the secular decline in real interest rates is driven to a large extent by lower economic growth.

Finally , we assess the sensitivity of our estimates to assumptions about fiscal policy in the presence of a permanent change in trend growth. We estimate the specification in which the fiscal authority updates g in Equation (23) when the change in z happens so that the size of government, g/y, in the final regime is the same as in the initial one. Under this alternative specification for fiscal policy, trend growth in the final regime is estimated to be 1.6% per year. This estimate is closer to the unobserved components model, but the log marginal density falls to 5501.8 which implies that this specification does not fit the data as well. Figure 11 compares the estimated transitional dynamics in the two cases. As the figure shows, the case in which the government spending to output ratio is the same in the final regime requires larger shocks to account for the deviations from the estimated transitional dynamics in sample, in particular throughout the 2000's.

Figure 11: Estimated Transitional Dynamics:
Government spending to GDP ratio



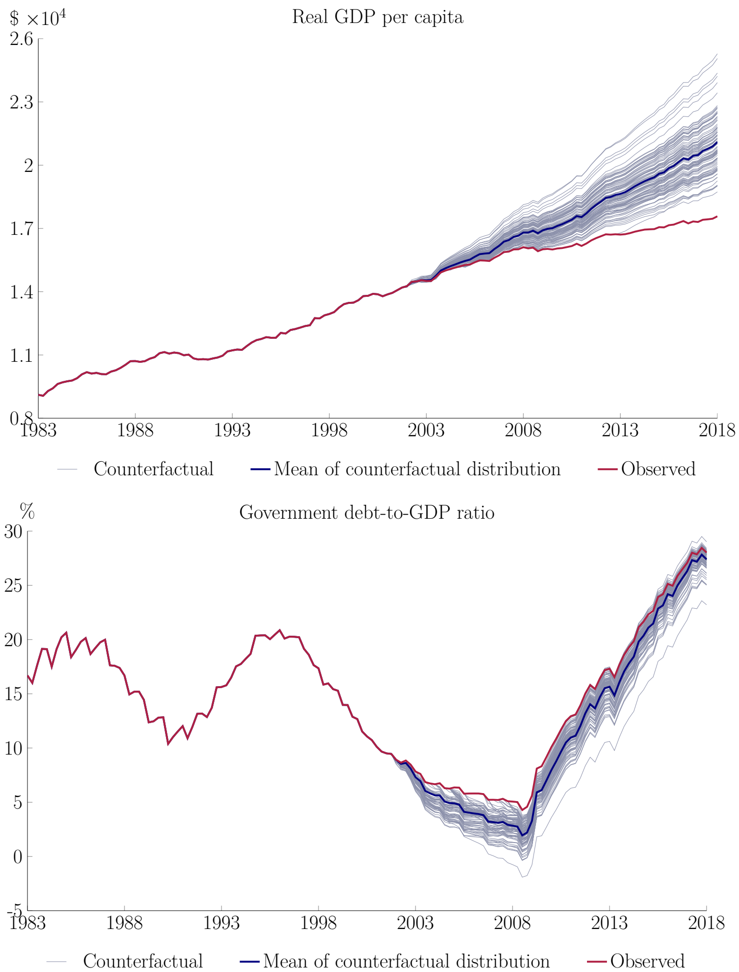
Sources: ABS; AOFM; Authors' calculations

5.7 Counterfactual Analysis

Next, we examine the path of the economy in the absence of the slowdown. We draw from the posterior and at each draw compute the smoothed structural shocks. We then use these shocks to compute what the evolution of the economy would have been under the assumption that $\Delta z = 0$, that is assuming there was no reduction in trend growth.

Figure 12 plots the posterior distribution of counterfactual paths for the level of output per capita and for the government debt to output ratio. At the end of our sample, by 2018:Q1 actual output per capita is $17,575. At the mean of the posterior distribution of the counterfactual paths, by 2018:Q1, output per capita would have been 20% higher, around $21,097. The cumulative loss of output over the whole sample at the mean is estimated to be $87,304, equivalent to more than one time annual GDP per capita.

Figure 12: Counterfactual Paths of Observable Variables in Absence of Trend Growth Slowdown



Sources: ABS; Authors' calculations

The differences in the evolution of the government debt to output ratio are, however, less staggering. As we argued above, the slowdown in trend growth increases the debt to output ratio given the fall in tax revenues. The fall in the government spending to output ratio together with the endogenous responses of the private sector, however, offsets some of this effect. From the estimated transitional dynamics we see that the government debt to annual output ratio increases on average by around 2 percentage points at the peak of the transition. Towards the end of the sample we find that in the absence of a change in trend growth, the government debt to output ratio would have been only around 0.7 percentage point lower.

6 Conclusion

It seems increasingly evident that trend growth around the world has slowed down. In this paper, we set up a small open economy model to estimate the magnitude of the slowdown and assess what some of the fiscal implications are.

We find strong evidence in favour of a permanent slowdown in trend growth with a structural model under different specifications of fiscal policy; we also find strong evidence using a statistical unobserved components model. This result is consistent with findings in the literature. The estimation with the structural model points to a somewhat more pronounced slowdown than what the statistical unobserved components model suggests. With the help of estimated transitional dynamics, we examine why this is the case: the real interest rates and the behaviour of the government spending to output ratio suggest that the slowdown is more pronounced than is implied by the GDP per capita series alone. The posterior distribution from the benchmark structural model, however, contains the modal estimates from every other specification. But more important than the particular value of trend growth is the fact that the structural model helps uncover the nature of the private and public sector responses to the slowdown. The private sector responds by increasing the accumulation of inputs and any specification of fiscal policy rules consistent with a stable equilibrium ties the fiscal policy response – government spending and tax revenues – to the size of the economy. These responses act as automatic stabilizers.

The hypothesis that there is a constant government spending to output ratio across different balanced growth paths has little support in our data. The alternative hypothesis where the government spending to output ratio shrinks over the sample fits our data better. This raises the issue of how one should model fiscal policy when the balanced growth path changes, in particular how the government budget constraint is assumed to be satisfied in the long-run. We have assumed that in both cases, lump-sum transfers adjust as necessary to balance the budget in the long-run. Alternatively, the budget constraint could be satisfied in the long-run by allowing the government to change its target debt to output ratio. According to our estimates, the slowdown reduces the real interest rate by 2 percentage points which increases tax revenues from consumption and would therefore allow the government to increase the target debt to output ratio from 13.4 to 25.5 per cent. Thus, a low growth environment can support higher levels of public debt but not for reasons advanced in Blanchard (2019) which relate to $r < z$. In our case it is always the case that $r > z$, but the increase in c/y is what allows the government to carry a higher debt to output in steady state.

There are questions we leave for future research such as alternative assumptions of how the budget constraint could be satisfied in the long-run or specifications as well as specifications of fiscal policy with government investment and capital as in Pappa (2009). We also consider permanent changes in trend growth in the neoclassical stochastic growth model in which technology follows an exogenous process. A permanent fall in trend growth triggers an initial fall in consumption and an accumulation of capital which eventually places the economy on a balanced growth with a higher level of output and capital per effective worker. From the perspective of fiscal policy, this endogenous response expands tax bases and works as an automatic stabilizer. In endogenous growth models of the kind proposed by Anzoategui et al. (2019), Bianchi et al. (2019) and Lucas (1988), a permanent fall in trend growth would also trigger a process of capital accumulation and increase capital per effective worker. This is because in response to a slowdown in the productivity of R&D, households would respond endogenously by shifting away from human capital accumulation and towards capital accumulation. But trend growth in endogenous growth models is pinned down, not by a single parameter like z as is the case here, but as a non-linear function of many parameters. Studying permanent changes in trend growth in endogenous growth models is therefore an exciting avenue for future research.

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