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Hysteresis and Full Employment in a Small Open Economy

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Keywords

Hysteresis, open economy macroeconomics, monetary policy, fiscal policy.

JEL Classification

E32, E63, F41

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Hysteresis and Full Employment in a Small Open Economy

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Abstract

We simulate a small open economy Two Agent New Keynesian (TANK) model featuring 'learning by doing' in production whereby changes in employment generate hysteresis in productivity and output. Credit constraints and hysteresis amplify the efficacy of fiscal stimulus in a small open economy with a floating exchange rate and inflation-targeting central bank such that output multipliers can exceed unity; welfare multipliers can be positive; and the degree of hysteresis, output and employment multipliers match empirical evidence well. Fiscal stimulus helps reverse output hysteresis, and price-level targeting provides superior macroeconomic stabilisation compared to other simple monetary rules combined with fiscal stimulus.

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1 Introduction

This paper is primarily motivated by ongoing debates concerning the efficacy of fiscal stimulus as a tool to fight demand driven recessions in small open economies with inflation-targeting central banks (see Makin, 2016). In particular, we explore the implications for the interaction of fiscal and monetary policy of introducing hysteresis effects and credit constrained households into a workhorse small open economy New Keynesian model. We also explore the consequences of alternate simple monetary policy rules for the efficacy of fiscal stimulus in this context.

This exploration is set against ongoing debates following the Global Financial Crisis (GFC) regarding the efficacy of fiscal stimulus. On the one hand a range of New Keynesian Dynamic Stochastic General Equilibrium (DSGE) models, including those presented by Christiano et al. (2011), Eggertsson (2011), and Woodford (2011), suggest that fiscal multipliers may be greater than one in a closed economy setting only when nominal interest rates are constrained by the zero lower bound (ZLB). However, Debortoli et al. (2019) present evidence challenging the empirical relevance of the ZLB to macroeconomic outcomes. Further, recent empirical studies including Auerbach and Gorodnichenko (2012a and 2012b), Fazzari et al. (2015), and Riera-Crichton et al. (2015) suggest that fiscal multipliers can be greater than one in a broader range of recessionary situations, even in small open economies (see IMF, 2012; Riera-Crichton et al., 2015; and Auerbach et al., 2019). These findings are relevant in the Australian context because interest rates were not constrained by the ZLB following the GFC. They also suggest the need for further development of the workhorse New Keynesian model to help explain how fiscal policy can be effective in more general recessionary conditions.

Debate has also surrounded whether a movement away from inflation targeting would be optimal in the post-GFC era. For example Eggertsson et al. (2020), Woodford (2012 and 2013), and Sumner (2012 and 2017) have advocated for a shift to a nominal income level targeting rule; McCallum (2015) a nominal income growth targeting rule; and Bernanke (2017) and Bernanke et al. (2019) temporary price level targeting as a form of forward guidance where interest rates are constrained by the ZLB. This debate has not addressed questions concerning the interaction of monetary and fiscal policy in the open economy context, hysteresis, and agent heterogeneity.

Further, Ball (2014), Bianchi et al. (2019), Blanchard et al. (2015), Cerra and Saxena (2005), Cerra et al. (2013), Cerra and Saxena (2017), Cerra et al. (2020), Fatás and Summers (2018), Gechert et al. (2019), and Jordà et al. (2020) have found broad empirical support for the hysteresis hypothesis, whereby demand driven recessions can have highly persistent, or even permanent effects, on the level of output and total factor productivity. On the other hand, Hall and Kudlyak (2020) and Jordà et al. (2020) have observed the tendency of employment and unemployment to recover following recessions, whereas output and productivity commonly do not recover to levels that would be predicted based on their pre-recession trends.

The dichotomy between permanent or highly persistent loss of output relative to trend following recessions, and employment returning to trend is also reflected in recent Australian data. To demonstrate this fact we follow the method of Blanchard et al. (2015) to determine the deviation of real output from its pre-recession trend following the 1990-91 recession and the GFC. Estimates of the evolution of output (blue) relative to trend (red) for the ten years following a Harding and Pagan (2002) business cycle peak are presented in Figure 1 below. Following the December 1990 cyclical peak output declined by 6.2 per cent relative to trend by the September quarter of 1993, whereas following the September 2008 cyclical peak output declined by only 2.2 per cent relative to trend by March 2011. Output failed to return to its Blanchard et al. (2015) pre-recession trend following each episode.

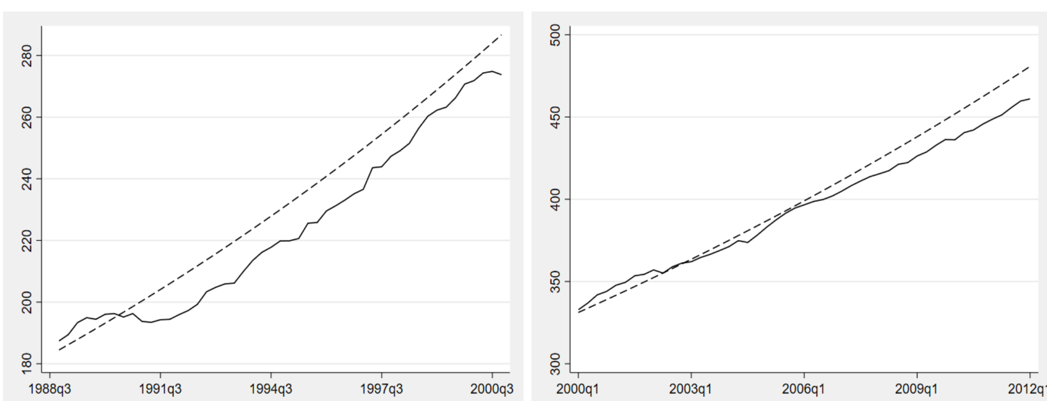

Figure 1: Real GDP (solid) relative to trend (dashed), $A billion seasonally adjusted, source: ABS 5206.0

A key historical difference between each of these business cycle episodes was that a large scale discretionary fiscal stimulus program was implemented during the GFC period; whereas this was not the case following the 1990-91 recession. Meanwhile, Figure 2 indicates that the employment to population ratio has demonstrated a strong tendency to recover in absolute terms following all recent Australian recessions.

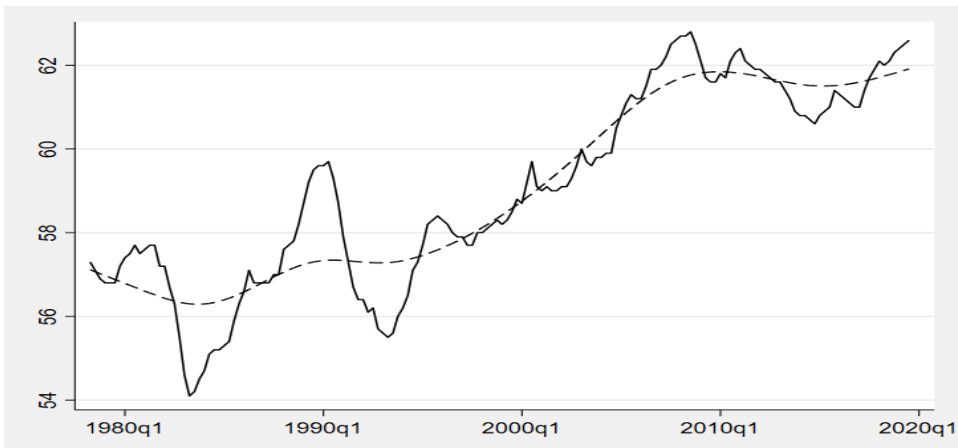

Figure 2: Employment, per cent of working age population, seasonally adjusted (solid); HP trend, $\lambda = 10,000$ (dashed), source: ABS 6202.0

In response to these observations, an emerging literature has explored the fiscal (Engler and Tervala, 2018; D'Alessandro et al., 2019) and monetary policy (Reifschneider et al., 2015; Moran and Queralto, 2018; Acharya et al., 2019; Bianchi et al., 2019; Garga and Singh, 2019; and Jordá et al., 2020) consequences of output hysteresis. Although, none of these papers have focused on the small open economy setting. Further, no studies have formally modelled the implications of hysteresis for the joint application of monetary and fiscal stimulus.

A growing number of papers have also focused on the relevance of credit constraints and agent heterogeneity to fiscal policy (see Galí et al., 2007; Li and Spencer, 2016; and McManus et al., 2020) and monetary policy (see McKay et al. 2016; and Kaplan et al. 2018). With the exception of Li and Spencer (2016), these papers have not utilised a small open economy framework. With unconstrained monetary policy, small open economy models featuring agent heterogeneity or hysteresis effects alone have not been able to generate output multipliers greater than one.

To address these issues this paper extends the Two Agent New Keynesian (TANK) model into a small open economy environment where changes in the level of employment endogenously affect the level of human capital formation in the economy, resulting in highly persistent effects on the levels of output and productivity. A fraction of workers are assumed not have access to credit markets, and cannot smooth their consumption over time. In the spirit of Arrow (1962), Stadler (1990), Chang et al. (2002) and Engler and Tervala (2018), the production technology incorporates a 'learning by doing' mechanism where changes in employment lead to highly persistent shifts in the level of total factor productivity (TFP) and output. We estimate model-consistent parameters for the 'learning by doing' process using recent Australian data. Government is assumed to pursue a balanced budget fiscal strategy, while the monetary authority follows a Henderson and McKibbin (1993)/ Taylor (1993) type rule.

In the workhorse New Keynesian DSGE model without hysteresis or credit constraints, recessions are short-lived, and output rapidly returns to its pre-recession trend. In these models it is very difficult to rationalise stabilisation policy on a welfare or cost-benefit basis (as in Lucas, 1987 and 2003). However, in reality recoveries are often slow, and it is common for the level of output to not return to its pre-recession trend following recessions (see Ball, 2014; Blanchard et al., 2015; and Cerra et al., 2020). Cerra at el. (2020) and Tervala (2021) argue that the potential benefits of stabilisation policy are much higher in the presence of hysteresis because it increases the welfare costs of recessions. We show that incorporating hysteresis and credit constraints into the New Keynesian model improves its ability to account for slow and incomplete recoveries.

In this paper we demonstrate that incorporating hysteresis and credit constraints into the model generates empirically plausible degrees of hysteresis based on the evidence of Furceri at al. (2021), Kienzler and Schmid (2014) and Rawdanowicz et al. (2014); and improves the ability of the model to qualitatively match medium-term dynamics in the Australian economy in the post-GFC period. The inclusion of credit constrained households generates different short-run dynamics for output and employment in response to demand shocks, such that employment may return to trend within standard business cycle durations, whereas output need not. This addresses a short-coming of other contemporary open economy New

Keynesian models such as Galí and Monacelli (2005) where output and employment are assumed to exhibit identical dynamics.

Credit constrained agents and hysteresis help the model generate output multipliers of a comparable magnitude to those experienced in advanced economies during the immediate post-GFC period (see in particular IMF, 2012; and Auerbach and Gorodnichenko, 2012a and 2012b). Cumulative and net present value output multipliers can exceed unity in the presence of hysteresis and credit constraints, while employment multipliers are just under half the magnitude of output multipliers- broadly consistent with empirical evidence presented by Monacelli et al. (2010) and Auerbach et al. (2019). In models featuring hysteresis and credit constraints, fiscal stimulus can be welfare enhancing under plausible assumptions about the value of government spending in worker utility.

In terms of policy implications, we find that hysteresis and credit constraints amplify output multipliers, and make fiscal stimulus welfare increasing. This is because credit constraints increase the effect of fiscal stimulus on private consumption, while the hysteresis mechanism helps counteract crowding out via monetary policy and exchange rate offset. Our results also suggest that fiscal stimulus can help reverse hysteresis effects, and restore full employment more rapidly. Overall, the model provides a suggested mechanism whereby discretionary fiscal stimulus can help stabilise the economy and be welfare enhancing. This is the case even in a small open economy setting, with an inflation-targeting central bank, unconstrained monetary policy, and where agents rationally anticipate stimulus will be balanced budget financed through increased future tax liabilities (contra Valentine, 2011; Kirchner, 2019; and Makin, 2010, 2016 and 2019).

The paper also considers whether fiscal policy may have been more effective in the domestic economy under alternative simple monetary policy rules. Alternative rules considered include price-level targeting (PLT), nominal gross domestic product level (NGDPLT), and growth targeting (NGDPGT) rules. In the GFC scenario, PLT delivers superior output and employment stabilisation; and output, employment and welfare multipliers are all larger under PLT relative to the other rules. This is because in the open economy context PLT not only results in real interest rates being 'lower for longer' relative to other rules, but the real exchange rate also. The hysteresis mechanism also means that PLT is more accommodative of expansionary fiscal policy compared to the other simple rules. These findings strengthen the case for temporary PLT in response to demand driven recessions as recommended by Bernanke (2017) and Bernanke et al. (2019), and provide theoretical support for the Federal Reserve's adoption of a 'flexible form of average inflation targeting' (Powell, 2020). With credit constrained households and hysteresis, output, employment and worker welfare are always higher when monetary and fiscal stimulus are combined under all alternative monetary policy rules.

2 Model

The modelling environment features two regions, domestic and foreign. The domestic region is a small country, and the foreign region is modelled as a single large country. The environment features a continuum of infinitely lived workers and firms indexed by $z \in [0,1]$, n $(1-n)$ are domestic (foreign), with the global population of firms and workers both normalised to unit size.

2.1 Workers

This paper departs from the assumption of an aggregate representative worker in the spirit of the recent literature concerning Heterogeneous Agent New Keynesian (HANK) models (see Kaplan, et al., 2018; and McKay et al., 2016 and 2017), and following in particular the TANK approach of Galí et al. (2007) and Li and Spencer (2016). Debortoli and Galí (2017) demonstrate that more tractable TANK models can match the aggregate dynamics of more complicated HANK models featuring uninsurable labour income risk and borrowing constraints quite well.

In both regions a fraction $1-\lambda$ of workers have access to credit markets, and are able to smooth consumption over time. These workers are referred to as optimising or Ricardian workers. On the other hand λ can only consume out of current income and endowments. These are referred to as non-Ricardian workers. The utility function for all workers, Ricardian and non-Ricardian, home and foreign, is identically given as follows:

$$U_t(z) = E_t \sum_{s=t}^{\infty} \beta^{s-t} \epsilon_s^{TP} \big[logC_s - \frac{(l_s(z))^{1+1/\varphi}}{1+1/\varphi} + \varrho logG_s \big] \tag{1}$$

Where E_t is the expectations operator, β is the worker's discount rate, ϵ_s^{TP} is a time preference shock, C_t is an index of real consumer goods and services, $l_t(z)$ is workers' labour supply, and φ is the Frisch elasticity of labour supply. G_t is government spending at date t, and ϱ is the weight of government consumption in worker utility.

Ricardian workers hold bonds, own and receive dividends from firms, and pay a lump-sum tax to government. The nominal budget constraint for Ricardian workers in the domestic region is therefore given as follows:

$$\frac{B_t}{1-\lambda} = \frac{(1+i_{t-1})}{1-\lambda} B_{t-1} + w_t l_{R,t} - P_t C_{R,t} + \frac{v_t}{1-\lambda} - P_t T_{R,t} \tag{2}$$

Where $l_{R,t}$ and $C_{R,t}$ are the labour supply and consumption of Ricardian workers, w_t is the nominal wage, v_t are financial returns derived from domestic firms, and $T_{R,t}$ are lump sum taxes levied on Ricardian households. B_t is the nominal price of home country bonds with a pay off of \$1 dollar of home country currency in period $t+1$, i_t is the nominal interest rate on bonds.

Domestic bonds are assumed to be the only internationally traded assets, and we denote B_t as nominal domestic bonds held by domestic workers, and B_t^* as nominal domestic bonds held by foreign workers. Therefore, the asset market clearing condition is given as follows:

$$nB_t + (1-n)B_t^* = 0 \tag{3}$$

Foreign bonds denoted B_t^{*f} in foreign country currency can only be held by foreign Ricardian workers. The nominal budget constraint of Ricardian workers in the foreign economy is structurally very similar to that facing Ricardian workers in the domestic economy:

$$\frac{B_t^*}{(1-\lambda^*)S_t} + \frac{B_t^{*f}}{1-\lambda^*} = \frac{(1+i_{t-1})}{1-\lambda^*} \frac{B_{t-1}}{S_t} + \frac{(1+i_{t-1}^*)}{1-\lambda^*} B_{t-1}^{*f} + w_t^* l_{R,t}^* - P_t^* C_{R,t}^* + \frac{v_t^*}{1-\lambda^*} - P_t^* T_{R,t}^* \tag{4}$$

To close the model, a debt elastic risk premium is assumed over uncovered interest parity (UIP) following Schmitt Grohe and Uribe (2003) and Bergin (2006):

$$(1+i_t) = (1+i_t^*)\frac{S_{t+1}}{S_t} + \omega(exp(B_t)-1) \tag{5}$$

Where $\omega(exp(B_t)-1)$ is the country-specific risk premium.

The optimality conditions for Ricardian workers in the domestic and foreign economy are identical, and in the home economy are given by:

$$\beta(1+i_t)E_t\left(\frac{\epsilon_{t+1}^{TP}P_tC_{R,t}}{\epsilon_t^{TP}P_{t+1}C_{R,t+1}}\right) = 1 \tag{6}$$

$$l_{R,t}(z) = \left(\frac{w_t}{C_{R,t}P_t}\right)^{\varphi} \tag{7}$$

Non-Ricardian workers earn income from labour and pay lump sum taxes to their national government. However, they do not have access to credit markets, and therefore cannot smooth consumption over time. Further, they do not have any residual claim over the profits of firms. The non-Ricardian workers optimality conditions are therefore defined by their flow budget constraint, and their labour supply relation with the 'N' sub-script denoting 'Non-Ricardian'. The optimality conditions are as follows:

$$P_tC_{N,t} = w_tl_{N,t} - P_tT_{N,t} \tag{8}$$

$$l_{N,t}(z) = \left(\frac{w_t}{C_{N,t}P_t}\right)^{\varphi} \tag{9}$$

Aggregate consumption and labour supply in the home economy are therefore defined as follows, with the same identities holding for the foreign economy:

$$C_t = \lambda C_{N,t} + (1-\lambda)C_{R,t} \tag{10}$$

$$l_t = \lambda l_{N,t} + (1-\lambda)l_{R,t} \tag{11}$$

Turning to the transnational dimension of workers' consumption decisions, the private real consumption index is given by:

$$C_t = \left[(\alpha n)^{1/\psi}(C_t^h)^{\frac{\psi-1}{\psi}} + (1-\alpha n)^{1/\psi}(C_t^f)^{\frac{\psi-1}{\psi}}\right]^{\frac{\psi}{\psi-1}} \quad (12)$$

Here C_t^h and C_t^f are indexes of domestically and foreign produced goods respectively, αn represents the share of domestic goods in the consumption basket with $\alpha > 1$ capturing the degree of home bias, and ψ capturing the cross-country substitutability of domestic and foreign goods. Consumption indexes for the domestic and foreign goods are given by:

$$C_t^h = \left[n^{-\frac{1}{\theta}} \int_0^n (c_t^h(z))^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}} \quad (13)$$

$$C_t^f = \left[(1-n)^{-\frac{1}{\theta}} \int_0^n (c_t^f(z))^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}} \quad (14)$$

Where θ is the elasticity of substitution between goods produced in the same country of origin, and $c_t^h(z)$ $(c_t^f(z))$ represents the domestic workers' consumption of the domestic (foreign) good z.

Private demand functions for domestic (foreign) goods by domestic (foreign) workers are given as follows, with the demand functions of foreign workers asterisked:

$$c_t^h(z) = \left[\frac{p_t^h(z)}{P_t^h}\right]^{-\theta} \left[\frac{P_t^h}{P_t}\right]^{-\psi} \alpha C_t \quad (15)$$

$$c_t^f(z) = \left[\frac{p_t^f(z)}{P_t^f}\right]^{-\theta} \left[\frac{P_t^f}{P_t}\right]^{-\psi} \left[\frac{1-\alpha n}{1-n}\right] C_t \quad (16)$$

$$c_t^{*h}(z) = \left[\frac{p_t^{*h}(z)}{P_t^{*h}}\right]^{-\theta} \left[\frac{P_t^{*h}}{P_t^*}\right]^{-\psi} \alpha^* C_t^* \quad (17)$$

$$c_t^{*f}(z) = \left[\frac{p_t^{*f}(z)}{P_t^{*f}}\right]^{-\theta} \left[\frac{P_t^{*f}}{P_t^*}\right]^{-\psi} \left[\frac{1-\alpha^* n}{1-n}\right] C_t^* \quad (18)$$

Where $p_t^h(z)$ and $p_t^f(z)$ represent the home country price of home and foreign produced goods respectively. P_t^h and P_t^f represent the consumer price indexes in the home and foreign countries, and C_t^h and C_t^f are the respective consumption baskets. All price indexes are expressed in domestic currency terms, and foreign currency indexes are denoted by an asterisk. Domestic price indexes are given by:

$$P_t^h = \left[n^{-1} \int_0^n p_t^h(z)^{1-\theta} dz\right]^{\frac{1}{1-\theta}} \tag{19}$$

$$P_t^f = \left[(1-n)^{-1} \int_0^n p_t^f(z)^{1-\theta} dz\right]^{\frac{1}{1-\theta}} \tag{20}$$

$$P_t = \left[\alpha n (P_t^h)^{1-\psi} + (1-\alpha n)(P_t^f)^{1-\psi}\right]^{\frac{1}{1-\psi}} \tag{21}$$

2.2 Firms

Firms are assumed to produce a differentiated good with capital in fixed supply of one unit. The production technology of firms is therefore given as follows:

$$y_t(z) = a_t(z) l_t(z) \tag{22}$$

With $y_t(z)$ representing the output of firm z, $a_t(z)$ the level of TFP, and $l_t(z)$ the labour supply utilised by the firm. The Auerbach et al. (2019) finding of no discernable crowding out of private capital accumulation related to government consumption provides an empirical rationale to exclude physical capital from the production technology. As does the finding of Christian (2010, 2014) that the stock of human capital may be significantly larger than the stock of physical capital. Following Chan et al. (2002) and Engler and Tervala (2018) hysteresis effects are assumed to emerge in production through 'learning by doing'. As worker employment duration increases they become more efficient at performing job tasks, and labour productivity increases. In the simple production function employed in this model environment, TFP is equivalent to labour productivity. Therefore, the level of employee skill and TFP accumulates over time based on the level of employment in the economy which is reflected in the following log-linear process:

$$\hat{a}_t(z) = \phi \hat{a}_{t-1}(z) + \eta \hat{l}_{t-1}(z) \tag{23}$$

Where hatted variables represent deviations from steady state. This equation formalises the notion that the level of employment in the current period effects the level of productivity in the next period with elasticity η. If $\phi = 1$ changes in employment will permanently change the level of TFP, and with $0 < \phi < 1$ the level of employment has a persistent effect on the level of TFP that erodes over time.

The firm in the home country is assumed to maximise profits:

$$v_t(z) = p_t^h(z) y_t^d(z) - w_t l_t(z) \tag{24}$$

subject to the production technology (equation (22)) and demand for its products from consumers and government given by:

$$\begin{aligned} y_t^d(z)) = & \left[\frac{p_t^h(z)}{P_t^h}\right]^{-\theta} \left[\frac{P_t^h}{P_t}\right]^{-\psi} \alpha n (C_t + G_t) \\ & + \left[\frac{p_t^h(z)}{S_t P_t^{*h}}\right]^{-\theta} \left[\frac{S_t P_t^{*h}}{S_t P_t^*}\right]^{-\psi} (1-n)\alpha^* (C_t^* + G_t^*) \end{aligned} \tag{25}$$

Under the assumption of no rigidities in price setting, profit maximisation with respect to $p_t^h(z)$ implies the following solution:

$$p_t^h(z) = \frac{\theta}{\theta - 1} \frac{w_t}{a_t(z)} \tag{26}$$

Price stickiness is introduced via the familiar Calvo (1983) algorithm of stochastic price adjustment where firms can reset their price in each period with a probability $1 - \gamma$ that is independent of time. Under Calvo pricing the firm seeks to maximise the discounted present value of expected future profits:

$$\max_{p_t^h(z)} V_t(z) = E_t \sum_{s=t}^{\infty} \gamma^{s-t} Q_{t,s} \frac{v_s(z)}{P_s} \tag{27}$$

With the stochastic discount factor between periods t and s given by $\xi_{t,s}$, the solution for $p_t^h(z)$ is:

$$p_t^h(z) = \frac{\theta}{\theta - 1} \frac{E_t \sum_{s=t}^{\infty} \gamma^{s-t} \xi_{t,s} Q_s \frac{w_s}{a_s(z)}}{E_t \sum_{s=t}^{\infty} \gamma^{s-t} \xi_{t,s} Q_s} \tag{28}$$

With

$$
\begin{aligned}
Q_s = & \left(\frac{1}{P_s^h}\right)^{-\theta}\left(\frac{P_s^h}{P_s}\right)^{-\psi}\alpha n\left(\frac{C_s+G_s}{P_s}\right) \\
& +\left(\frac{1}{S_s P_s^{*h}}\right)^{-\theta}\left(\frac{P_s^h}{S_s P_s^*}\right)^{-\psi}(1-n)\alpha^*\left(\frac{C_s^*+G_s^*}{P_s}\right)
\end{aligned}
\tag{29}
$$

Log-linearising equation (29) results in a version of the New Keynesian Phillips curve:

$$\hat{p}_t^h(z) = \beta\gamma E_t(\hat{p}_{t+1}^h(z)) + (1-\beta\gamma)(\hat{w}_t - \hat{a}_t(z)) + \epsilon_t^p \tag{30}$$

Where ϵ_t^p is a zero mean cost push shock.

2.3 Policy

Public consumption indexes are assumed to be structurally identical to private consumption indexes, and public demand functions for domestic and foreign produced goods are defined in an analogous way to private demand functions. Following Rendahl (2016) we assume government follows a simple balanced budget fiscal rule which is consistent, at least in expectational terms, with Australia's medium-term fiscal strategy (see Gruen and Sayegh, 2005):

$$P_t T_t = P_t G_t \tag{31}$$

Where $T_t \equiv \lambda T_{N,t} + (1-\lambda)T_{R,t}$. We assume that Ricardian and Non-Ricardian workers face the same rate of tax which implies that their tax payments increase in proportion to their population shares when government spending increases. Defining $\hat{g}_t = (G_t - G)/Y$ and $\hat{t}_t = (T_t - T)/Y$, the government budget constraint can be simplified to the following expression in terms of deviations from steady state:

$$\hat{g}_t = \hat{t}_t \tag{32}$$

Government spending is assumed to evolve according to an exogenous autoregressive process of the following form:

$$\hat{g}_t = \rho^g \hat{g}_{t-1} + \epsilon_t^g \tag{33}$$

Where ρ^g is between zero and one, and ϵ_t^g is an i.i.d government spending shock variable with zero mean.

The Reserve Bank in the model is assumed to follow a standard Henderson-McKibbin-Taylor type monetary reaction function of the following form:

$$\hat{i}_t = \mu_1 \hat{i}_{t-1} + (1-\mu_1)(\mu_2 \Delta \hat{P}_t + \mu_3 \hat{Y}_t) + \epsilon_t^i \tag{34}$$

Which assumes that the monetary authority responds to deviations of inflation and output from the initial steady state with some interest rate smoothing. ϵ_t^i is a zero mean i.i.d monetary policy shock.

2.4 Equilibrium conditions

Combining equations (2), (8) (24), and (31) yields the overall budget constraint of the domestic economy:

$$B_t - (1 + i_{t-1})B_{t-1} = p_t^h(z)y_t(z) - P_tC_t - P_tG_t \tag{35}$$

The model is then log-linearised around a symmetric steady state with domestic and foreign bonds assumed to be in zero net supply. For simplicity, productivity is normalised to one and public spending zero in the initial steady state. Combining equations (7), (9), (22) and (26) yields the initial steady state level of employment:

$$l_0(z) = y_0 = C_0 = \left(\frac{(\theta-1)}{\theta}\right)^{\frac{1}{1+\frac{1}{\varphi}}} \tag{36}$$

The log-linearised Euler condition for optimising households can be expressed as follows:

$$\hat{c}_{R,t} = E_t\{\hat{c}_{R,t+1}\} - (\hat{i}_t - E_t\{\hat{\pi}_{t+1}\} + E_t\{\Delta\hat{\epsilon}_{t+1}^{TP}\}) \tag{37}$$

While the log-linearised consumption function for Non-Ricardian households is given by:

$$\hat{c}_{N,t} = \left(\frac{wl_N}{PC_N}\right)(\hat{w}_t - \hat{p}_t + \hat{l}_{N,t}) - \left(\frac{y_0}{C_N}\right)\hat{t}_{N,t} \tag{38}$$

Assuming a symmetric equilibrium where $C_R = C_N = C_0 = y_0 = l_0(z)$, and a perfectly competitive labour market such that $l_R = l_N = l_0(z)$:

$$\frac{wl_N}{PC_N} = \left(\frac{(\theta-1)}{\theta}\right)^{\frac{1}{1+\frac{1}{\varphi}}} \left(\left(\frac{(\theta-1)}{\theta}\right)^{\frac{1}{1+\frac{1}{\varphi}}}\right)^{\varphi} \equiv \chi \tag{39}$$

and

$$\frac{y_0}{C_N} = 1 \tag{40}$$

The log-linearised expressions for aggregate consumption and labour supply are given as follows:

$$\hat{c}_t = \lambda\hat{c}_{N,t} + (1-\lambda)c_{R,t} \tag{41}$$

$$\hat{l}_t = \lambda\hat{l}_{N,t} + (1-\lambda)\hat{l}_{R,t} \tag{42}$$

Noting that

$$\hat{l}_{N,t} = \varphi(\hat{w}_t - \hat{p}_t - \hat{c}_{N,t}) \tag{43}$$

and

$$\hat{w}_t - \hat{p}_t = \hat{c}_t + \varphi^{-1}\hat{l}_t \tag{44}$$

and substituting these results into equation (38) yields the following:

$$\hat{c}_{N,t} = \frac{\chi(1+\varphi)}{(1+\chi\varphi)}\hat{c}_t + \frac{\chi(1+\varphi^{-1})}{(1+\chi\varphi)}\hat{l}_t - \frac{1}{(1+\chi\varphi)}\hat{t}_{N,t} \tag{45}$$

Applying the operator $(1-L^{-1})$ to equation (41) provides us with:

$$\hat{c}_t - E_t\hat{c}_{t+1} = \lambda[\hat{c}_{N,t} - E_t\hat{c}_{N,t+1}] + (1-\lambda)[\hat{c}_{R,t} - E_t\hat{c}_{R,t+1}] \tag{46}$$

Then substituting equations (36), (42), (43), and (44) into (45) yields the equilibrium Euler condition for aggregate consumption:

$$\hat{c}_t = E_t\{\hat{c}_{t+1}\} - \sigma(\hat{i}_t - E_t\{\hat{\pi}_{t+1}\} + \Delta\hat{\epsilon}^{TP}_{t+1}) - \Gamma E_t\{\Delta\hat{l}_{t+1}\} + \kappa E_t\{\Delta\hat{t}_{N,t+1}\} \tag{47}$$

Where

$$\sigma = (1-\lambda)\left(1-\lambda\frac{\chi(1+\varphi)}{(1+\chi\varphi)}\right)^{-1} \tag{48}$$

$$\Gamma = \lambda\left(\frac{\chi(1+\varphi^{-1})}{(1+\chi\varphi)}\right)\left(1-\lambda\frac{\chi(1+\varphi)}{(1+\chi\varphi)}\right)^{-1} \tag{49}$$

and

$$\kappa = \frac{\lambda}{(1+\chi\varphi)}\left(1-\lambda\frac{\chi(1+\varphi)}{(1+\chi\varphi)}\right)^{-1} \tag{50}$$

Thus the aggregate Euler condition for consumption is the only equilibrium condition that displays dependence on the fraction of Non-Ricardian workers. The presence of Non-Ricardian workers creates a direct effect of the level of employment in the economy on consumption in addition to the indirect real interest rate channel of the workhorse New Keynesian small open economy model without credit constrained workers. The model is solved using the algorithm proposed for solving rational expectations models by Klein (2000), implemented using software developed by McCallum (2001).

3 Calibration

3.1 Hysteresis process

An obvious empirical challenge confronting a theory of business cycles where human capital plays a central role is that no statistical agency currently maintains human capital accounts. This is in part due to controversies regarding measurement (see Jorgenson and Fraumeni, 1989 and 1992; Christian, 2010 and 2014; Abraham, 2010; McGrattan, 2010; and Fraumeni et al., 2015). Nonetheless our model suggests a relatively straightforward, albeit arguably narrow, way to empirically capture the value of human capital. In our model the first order conditions for labour imply that real wages are driven by productivity, which in the 'learning by doing' model can be represented as a moving average of past employment.

$$\hat{w}_t - \hat{p}_t = \hat{a}_t(z) = \eta\sum_{k=0}^{\infty}\phi^k \hat{l}_{t-1-k}(z) \tag{51}$$

Invoking Wold's Representation Theorem, equation 52 provides a model consistent empirical real wage equation that can be simply estimated via non-linear least squares.

$$\hat{w}_t - \hat{p}_t = \sum_{j=1}^{4} \beta_j (\hat{w}_{t-j} - \hat{p}_{t-j}) + \eta \sum_{k=0}^{4} \phi^k \hat{l}_{t-1-k} + \varepsilon_t \tag{52}$$

Where $0 < \eta < 1$, $0 < \phi < 1$, and $\sum_{j=1}^{4} \beta_j$ are constrained to unity, $\eta \sum_{k=0}^{4} \phi^k \hat{l}_{t-1-k} = 0$, and the real wage equation retains theoretical consistency with our structural model. To estimate this model we use the Wage Price Index (WPI) deflated using the Consumer Price Index (CPI) in log deviations from its Hodrick-Prescott filtered stochastic trend ($\lambda = 1600$) as the dependent variable. For the employment variable we use the employment level, employment to population ratio, quarterly hours worked, and quarterly hours worked per worker all measured in log deviations from their respective Hodrick-Prescott filtered stochastic trends ($\lambda = 1600$) also. Similar, although less precise, estimates for the primary parameters of interest were obtained when data was de-trended using the Hamilton (2018) Filter and Beveridge-Nelson Filter proposed by Kamber, Morley, and Wong (2018). Results are contained in Table 1 below.

Table 1: Human capital accumulation

	(1)	(2)	(3)	(4)
	Employment	Employment to population ratio	Hours worked	Hours worked per worker
β_1	0.94***	0.91***	0.93***	0.92***
	(0.66, 1.21)	(0.58, 1.15)	(0.63, 1.23)	(0.57, 1.26)
β_2	0.11	0.15	0.13	0.13
	(-0.24, 0.46)	(-0.24, 0.54)	(-0.27, 0.53)	(-0.28, 0.55)
β_3	-0.22*	-0.26*	-0.25*	-0.23*
	(-0.49, 0.03)	(-0.52, 0.01)	(-0.54, 0.04)	(-0.50, 0.04)
$\exp(\phi)$	0.93	0.91**	0.94	0.90
	(0.78, 1.10)	(0.84, 0.99)	(0.83, 1.07)	(0.72, 1.13)
$\exp(\eta)$	0.20**	0.27***	0.23***	0.30***
	(0.13, 0.31)	(0.18, 0.42)	(0.15, 0.34)	(0.16, 0.56)
R^2	0.44	0.47	0.45	0.45
BG LM test (pr.)	0.26	0.00	0.26	0.14
Harvey test (pr.)	0.32	0.43	0.08	0.26
Chow test (pr.)	0.36	0.44	0.15	0.12

Notes: ***,**,* represent statistical significance at the 0.01, 0.05 and 0.1 significance levels respectively. 95 per cent confidence intervals reported in brackets. Estimation period is 1998Q3 to 2019Q4. All variables expressed in log deviation from Hodrick-Prescott Filter trend ($\lambda = 1600$). Estimates for ϕ and η are exponentiated to facilitate direct comparison to the structural model $A_t(z) = A_{t-1}^{\phi}(z) L_{t-1}^{\eta}(z)$. BG LM test is a fourth order Breusch (1978) - Godfrey (1978) LM test with null of no serial correlation. Harvey test is the Harvey (1976) heteroskedasticity test with null of homoskedastic errors. The Chow test is the Chow (1960) break point test with assumed break date of 2009Q2, and null hypothesis of no structural break.

Although estimates for ϕ are generally statistically insignificant, they point to a likely range of values between 0.9 and 1, higher than the value of 0.8 suggested by Chang et al. (2002) based on US micro-econometric evidence. Estimates for η are statistically significant, and concentrated within the range of 0.2 to 0.3, again slightly higher than the range of 0.11 to 0.15 suggested by Chang et al. (2002), and the range of 0 to 0.2 suggested as reasonable for the US by De Long and Summers (2012). For the domestic region we use the calibration $\phi = 0.93$ and $\eta = 0.2$ based on results from the employment levels equation (Column 1), which is the most model consistent specification. For the international region we set $\phi^* = 0.96$ following Reifschneider et al. (2015) and $\eta^* = 0.13$ based on Chang et al. (2002). We also conduct robustness analysis using $\phi = \phi^* = 0.99$ following Engler and Tervala (2018) and $\phi = \phi^* = 0.8$ following Chang et al. (2002) and D'Alessandro et al. (2019); and $\eta = \eta^* = 0.11$ and $\eta = \eta^* = 0.30$.

3.2 Standard parameters

The workers' discount factor is set to $\beta = \beta^* = 0.99$, and the relative size of the home economy $n = 0.017$ is set to reflect the post-GFC average size of the Australian economy relative to world GDP in constant 2010 US dollar terms. The home bias parameter $\alpha = 46.5$ is calibrated to match the post-GFC average import to GDP ratio for Australia over the period 2008-2019 (0.21).

We set the Frisch elasticity of labour supply equal to unity in both regions $\varphi = \varphi^* = 1$. This is a common choice for Australian DSGE models, including Rees et al. (2016), Langcake and Robinson (2013) and Jääskelä and Nimark (2011). Chetty et al. (2013) argue that the Frisch elasticity should be set equal to 0.5 in macro models based on microeconomic evidence, while Keane and Rogerson (2012) argue that small micro elasticities can be consistent with large macro elasticities, and prefer a range of 1 to 2. Generally, larger elasticities are more appropriate for models focused on the extensive margin of the labour market as here. We conduct robustness analysis using $\varphi = \varphi^* = 0.5$ and $\varphi = \varphi^* = 2$.

A standard value suggested for the cross-country substitutability parameter ψ is 1.5 (see Dong, 2012). In the recent Australian context this calibration is employed by Langcake and Robinson (2013). However, where Bayesian estimation techniques are used parameter estimates vary between 0.58 in Justiano and Preston (2010) to 1.3 in Jääskelä and Nimark (2011). Therefore we select $\psi = 1$ which is also consistent with Li and Spencer (2016). We select $\theta = 6$ for the within-country substitutability parameter following Galí and Monacelli (2005). The country-specific risk premium for the Australian economy is $\omega = 0.001$ consistent with Rees et al. (2016).

Estimates of the Calvo parameter γ in recent Australian studies mostly range between 0.7 and 1. On the low side, Li and Spencer (2016) estimate a Calvo parameter of 0.38. Other estimates include 0.79 in Justiano and Preston (2010), 0.89 in Nimark (2009), 0.69 in Jääskelä and Nimark (2011), and 0.95 in Langcake and Robinson (2013). Based on these estimates γ is set to 0.85. For the foreign economy $\gamma^* = 0.75$ following Rabanal and Tuesta (2010) and Engler and Tervala (2018).

Australian estimates for the interest smoothing parameter μ_1 range from 0.49 in Li and Spencer (2016) to 0.87 in Nimark (2009). Given that most estimates are between 0.82 and 0.87, we select $\mu_1 = 0.85$. Estimates for the weight on inflation in the Taylor rule μ_2 vary between 0.41 in Nimark (2009) and 1.75 in Jääskelä and Nimark (2011), with most estimates close to the standard value of 1.5 which we select. Finally, values for the weight on output in the monetary policy rule vary between 0.02 in Nimark (2009) and 0.72 in Langcake and Robinson (2013), with most estimates between 0.10 and 0.30. Given these estimates we select $\mu_3 = 0.2$. For the foreign economy $\mu_1^* = 0.79$, $\mu_2^* = 1.5$, and $\mu_3^* = 0.5$ following Clarida et al. (2000).

We set $\lambda = 0.27$ based on ABS (2019) evidence that the proportion of households reporting no debt in Australia has been relatively stable at around 27 per cent between 2003-04 and 2017-18. This is probably a relatively conservative estimate of the proportion of Non-Ricardian agents in the model; for example Galí et al. (2007) set the proportion of Non-Ricardian households in their model to 50 per cent following the evidence of Campbell and Mankiw (1989). We set $\lambda^* = 0.3$ following Kaplan et al. (2014) who find 25 - 40 per cent of US households are Hand-to-Mouth (HtM), 30 per cent of households in Canada, the UK and Germany, and less than 20 per cent of households in France, Italy and Spain.

3.3 GFC scenario

Our GFC simulation assumes a large common global time preference shock that is equivalent to 14 per cent of initial consumption. The Australian share market All Ordinaries Index fell by 14 per cent in October 2008, and the US market fell by around 17 per cent over the same period. Concurrently the University of Michigan consumer sentiment index fell by 18 per cent over the month of October 2008, while Australian consumer sentiment data is unavailable over this time period. Overall, this evidence suggests that a common time preference shock of the magnitude proposed appears reasonable given changes in stock valuations and consumer confidence in the aftermath of the collapse of Lehman Brothers. Galí (2020) suggests values for the persistence of the time preference shock of between $\rho^{TP} = 0.91$ and $\rho^{TP} = 0.99$, and we set $\rho^{TP} = \rho^{TP^*} = 0.96$.

We also assume a domestic monetary policy shock equal to 425 basis points consistent with the Reserve Bank of Australia's reduction in the cash rate between September 2008 and April 2009. The foreign monetary policy shock is set equal to 250 basis points - half way between the 200 basis point reduction in the United States and 300 basis points in Europe at the onset of the GFC.

Finally, the shock to Australian Government spending is set equal to 5.6 per cent of GDP which is consistent with the overall increase in discretionary spending between 2008 and 2012 (see Charlton, 2019). The IMF (2009) assessed G20 discretionary fiscal expansions of 0.5 per cent of G20 GDP in 2008, 1.5 per cent in 2009, and -0.5 per cent in 2010, representing an increase equivalent to 1.2 per cent of world GDP over the three years. Therefore, the foreign fiscal shock is set equal to 1.2 per cent of GDP. We set $\rho^g = 0.9$ following Galí et al. (2007) and $\rho^{g^*} = 0.75$ following Iwata (2013) which helps represent the fact that Australia's fiscal response to the GFC was more persistent than other advanced economies.

4 Propagation of shocks in the model

The following section focuses on the dynamic response of the domestic economy to combined demand shocks, noting that the response of the foreign economy is qualitatively similar, albeit it with a more limited monetary and fiscal policy response.

4.1 Shock propagation without hysteresis and credit constraints

In these initial simulations credit constraints and hysteresis effects are suppressed ($\lambda = \lambda^* = 0$ and $\eta = \eta^* = \phi = \phi^* = 0$ respectively). Figure 3 depicts the evolution of the domestic economy in response to the common time preference and monetary shocks, with internationally coordinated fiscal stimulus 'With FE' and 'Without FE'. The model without hysteresis effects and credit constraints generates what may be regarded as standard insights from mainstream small open economy models along the lines of Monacelli and Galí (2005), Lubik and Schorfheide (2005, 2007), and Justiano and Preston (2010) when subjected to demand shocks. The comparatively large fiscal and monetary policy intervention helps reduce the impact of the GFC on output, while also resulting in the crowding out of private consumption. With the real exchange rate defined as $\frac{StP_t^*}{P_t}$ and terms of trade defined as the ratio of domestic export to import prices, the simple model does a reasonable job of matching their simultaneous depreciation at the outset of the GFC, and appreciation during the early phase of the recovery as would be expected based on Bergin (2006). Synonymous output and employment dynamics do not match historical empirical evidence well.

4.2 Shock propagation with hysteresis and credit constraints

Figure 4 shows the change in short-run dynamics in the domestic economy when hysteresis and credit constraints are incorporated into the model. Fiscal stimulus increases output, consumption and productivity while actually reducing inflation as in the empirical evidence presented for the US economy by D'Alessandro et al. (2019), and models that incorporate 'learning by doing' in the production technology including Engler and Tervala (2018) and D'Alessandro et al. (2019). With coordinated fiscal stimulus domestic consumption and output are significantly higher than they would have been without fiscal stimulus. Fiscal stimulus does not crowd out private consumption, with consumption significantly higher in the medium to long-term in particular. Employment can return to its initial trend within business frequencies, whereas output does not consistent with Jordà et al. (2020).

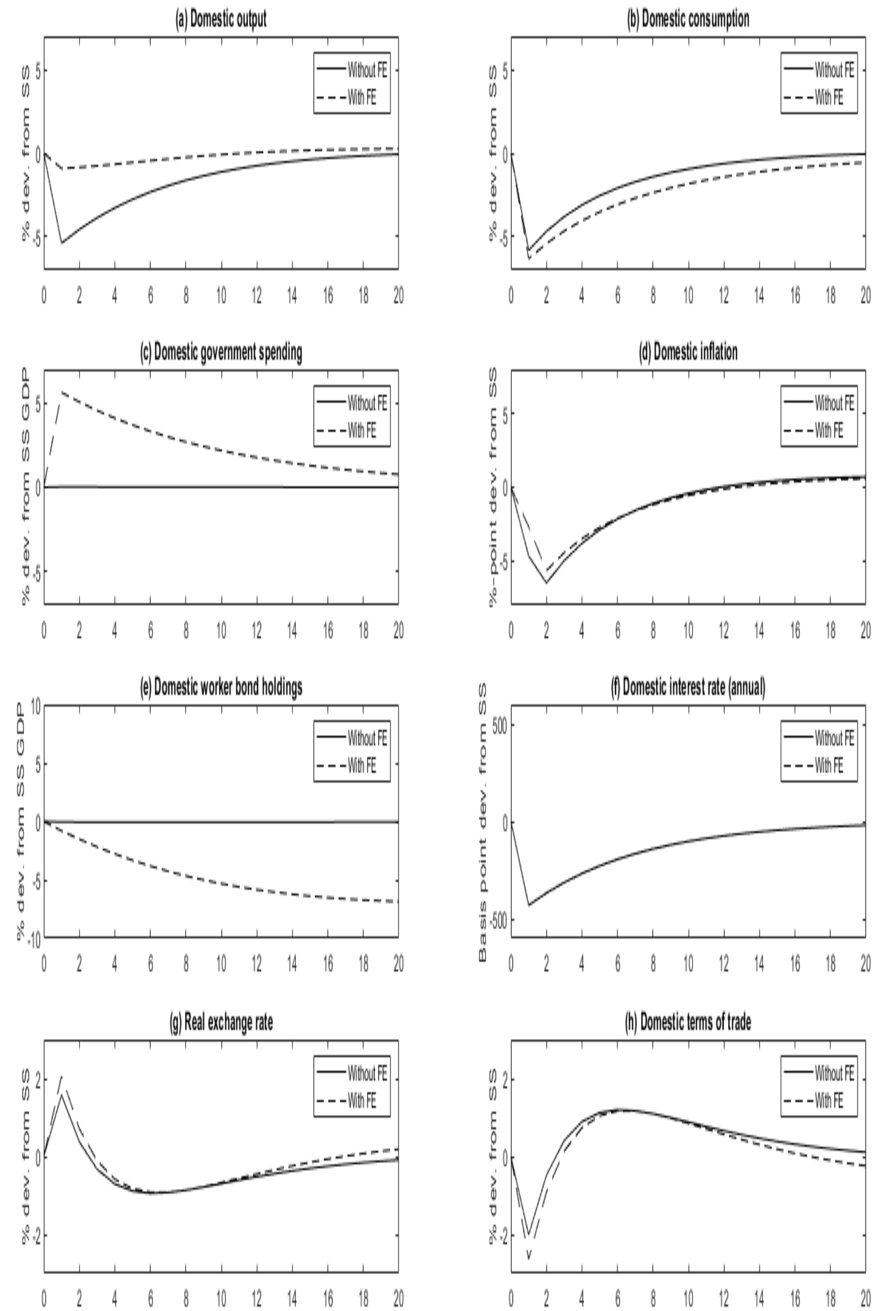

Figure 3: Domestic dynamics: Without hysteresis and credit constraints, with and without coordinated fiscal expansion (FE), quarterly

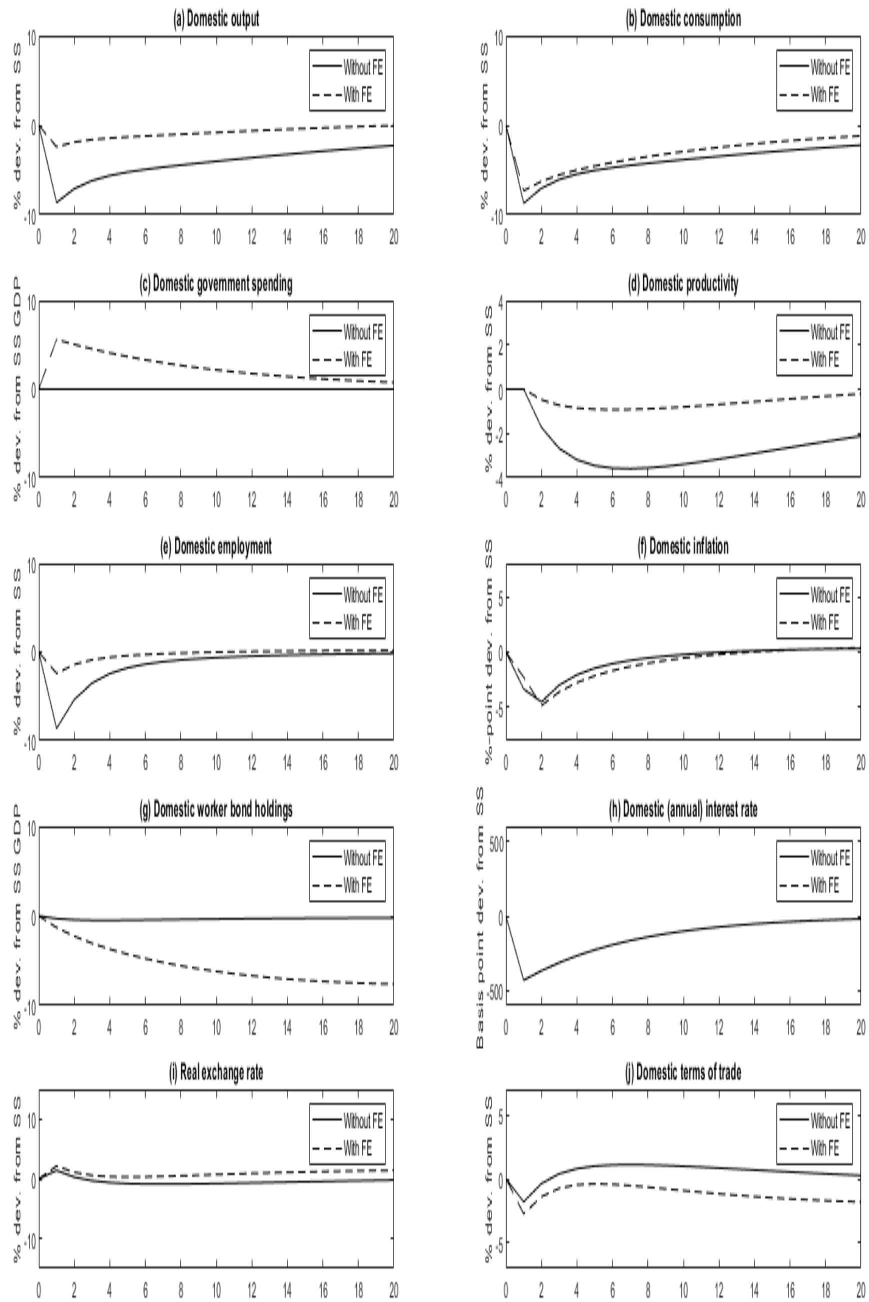

Figure 4: Domestic dynamics: With hysteresis and credit constraints, with and without coordinated fiscal expansion (FE), quarterly

The ratio of the peak fall in TFP relative to output in our model is 0.39, which compares closely to the empirical evidence presented by Furceri et al. (2021) who find a value of 0.42 following recessions in 18 advanced economies between 1970 and 2014. Defining the degree of hysteresis as the ratio of the fall in output in the final period to the fall in output in the initial period as in Kienzler and Schmid (2014) and Rawdanowicz et al. (2014), we find a degree of hysteresis of 0.19 after four years. This is towards the lower end of the 0.2 to 0.3 range suggested as reasonably by Kienzler and Schmid (2014). The degree of hysteresis falls to zero midway through the fifth year, which is consistent with the empirical evidence presented by Rawdanowicz et al. (2014) for the Australian economy. Our simulation implies that the degree of hysteresis was relatively low in Australia because it undertook a comparatively large fiscal stimulus program.

Short-term real exchange rate and terms of trade dynamics are similar to the model without hysteresis and credit constraints. Hysteresis effects imply that relative employment, and therefore productivity, will be higher under the scenario where fiscal stimulus is relatively larger in the domestic economy. This in turn implies lower domestic inflation and higher international competitiveness in the medium-term which translates into a lower real exchange rate and lower terms of trade over this time period compared to scenarios without fiscal expansion. The comparatively greater medium-term depreciation of the real exchange rate and terms of trade qualitatively matches Australia's post-GFC experience well.

4.3 A closer look at domestic output and employment dynamics

Figure 5 provides a comparison of output dynamics in the domestic economy under alternative assumptions regarding the presence or absence of hysteresis effects and credit constraints, and a coordinated fiscal expansion. Firstly, in the presence of credit constraints, hysteresis and a coordinated fiscal expansion, the model generates a reduction in GDP of roughly 2.4 per cent relative to steady state at peak. As discussed, this matches very closely the 2.2 per cent decline of GDP relative to trend that occurred between the December quarter of 2008 and the March quarter of 2011 (see Figure 1), albeit the cyclical trough in the data occurs much later than in the model. This is due to the prevalence of forward looking optimising agents in the model combined with the definition of the shock processes. These shortcomings are shared with the standard textbook New Keynesian open economy model.

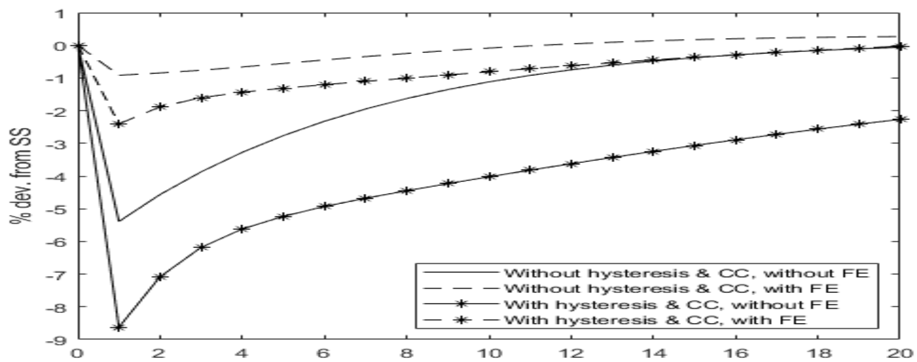

Figure 5: Domestic output dynamics with and without hysteresis and credit constraints (CC), with and without coordinated fiscal expansion (FE), quarterly

It is in the medium-term where the hysteresis mechanism greatly enhances the ability of the model to match the data. After two years the model generates output 1.0 per cent below initial trend, and 0.3 per cent after four years, compared to 1.0 per cent and 0.6 per cent in Figure 1, much closer than alternate model specifications. Interestingly, in the data output is 0.3 per cent below initial trend after 15 quarters, with the further 0.3 per cent decline in output in the 16th quarter post-GFC associated with the collapse of the Australian mining boom at the end of 2011 and through the early stages of 2012. Further, a key characteristic of the model with hysteresis is that the demand driven recession generates a highly persistent loss of output relative to pre-recession trend that need not be reversed within typical business cycle frequencies. In the baseline calibration it takes over 18 years for output to return to its pre-recession trend where there is no fiscal stimulus, and over 5 years with substantial fiscal stimulus. This is consistent with the empirical evidence presented by Cerra and Saxena (2005), Cerra et al. (2013), Cerra and Saxena (2017), Ball (2014), Blanchard et al. (2015), Fatás and Summers (2018) and Gechert et al. (2019). By contrast, models without hysteresis and credit constraints greatly over-estimate the level of GDP and the speed at which the economy will return to its initial trend in each scenario.

Figure 6 looks at domestic employment dynamics under alternative assumptions regarding the presence or absence of hysteresis effects and credit constraints, and a coordinated fiscal expansion. As noted, without hysteresis and credit constraints, output and employment dynamics are identical in the textbook New Keynesian small open economy model. This is obviously an undesirable feature of this model for policy analysis given that output and employment clearly have different dynamics in the data. In Figure 2 employment in Australia during the GFC employment declined by just under 2 per cent relative to trend between the September quarter of 2008 and the September quarter of 2009. In the model with hysteresis and credit constraints employment declines by 2.4 per cent relative to trend; however, given the definition of shock processes, rational expectations and the prevalence of forward looking agents in the model, again the cyclical trough occurs much sooner than in the data. Overall, the model does a better job of matching the short-term dynamics of employment compared to output, consistent with other New Keynesian models (see Monacelli et al., 2010). Whereas output fails to return to its pre-GFC trend within five years in the model, employment surpasses its pre-GFC trend after 11 quarters. In the data employment returns to its stochastic trend around 8 quarters after its September 2008 peak. Under the model with hysteresis and credit constraints it is possible for employment to return to its pre-recession trend within typical business cycle frequencies, while output need not. This feature of the model appears to match the general experience of many advanced economies well (see Jordà et al., 2020)), including Australia following the 1990-91 recession and the GFC.

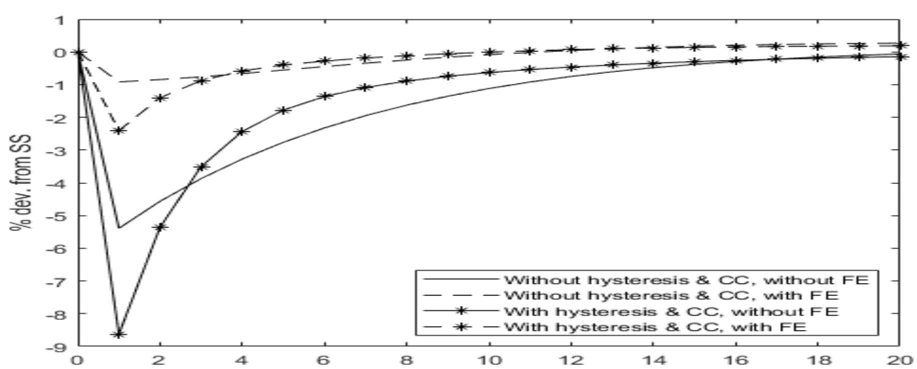

Figure 6: Domestic employment dynamics with and without hysteresis and credit constraints (CC), with and without coordinated fiscal expansion (FE), quarterly

5 Fiscal policy under hysteresis: Output, welfare and employment multipliers

This section seeks to evaluate the efficacy of fiscal stimulus through the calculation of output, employment and welfare multipliers. First, we define cumulative multipliers for output and employment as the difference in the cumulative change of output and employment in the case with a fiscal expansion (FE), and the cumulative change of output and employment in the case without a fiscal expansion (WFE), divided by the cumulative increase in government spending under the fiscal expansion scenario. That is:

$$CM^{Y} = \frac{\sum_h \hat{Y}_{t+h}^{FE} - \sum_h \hat{Y}_{t+h}^{WFE}}{\sum_h \hat{G}_{t+h}^{FE}} \tag{53}$$

and

$$CM^{l(z)} = \frac{\sum_h \hat{l}_{t+h}^{FE}(z) - \sum_h \hat{l}_{t+h}^{WFE}(z)}{\sum_h \hat{G}_{t+h}^{FE}} \tag{54}$$

Following Mountford and Uhlig (2009), Uhlig (2010) and Fisher and Peters (2010), we also calculate net present value multipliers for output which are derived as follows:

$$NPVM^{Y} = \frac{\sum_{s=t}^{h} \beta^{s-t}\hat{Y}_{s}^{FE} - \sum_{s=t}^{h} \beta^{s-t}\hat{Y}_{s}^{WFE}}{\sum_{s=t}^{h} \beta^{s-t}\hat{G}_{s}^{FE}} \tag{55}$$

Welfare multipliers are defined as the change in welfare in consumption equivalent terms associated with a unit increase in government spending as in Engler and Tervala (2018), Sims and Wolff (2018) and Rendahl (2016). The derivation of the welfare multiplier follows Engler and Tervala (2018) and is defined as:

$$WM = \frac{\mathcal{L}_t}{\sum_{s=t}^{h} \beta^{s-t}\hat{G}_{s}^{FE}} \tag{56}$$

Where $\mathcal{L}_t$ reflects the proportion of initial consumption that a domestic worker would be prepared to pay to be as well off in the fiscal expansion case as the alternative case, assuming labour supply remains constant.

Cumulative output and employment multipliers, and net present value output multipliers, are calculated over 16 quarters; while welfare multipliers are calculated over 2000 quarters.

As a central case, following Song et al. (2012) it is assumed that workers place a weight of 0.4 on government consumption relative to private consumption- and sensitivity analysis is included for the cases where government consumption is viewed as a complete waste ($\varrho = 0$), or of equivalent value to private consumption in worker utility ($\varrho = 1$).

Table 2 provides cumulative output and employment multiplier calculations, and net present value multiplier calculations for output derived from models including and excluding hysteresis effects and credit constraints. The inclusion of credit constraints and hysteresis in the model increases output multipliers, with hysteresis effects the largest contributor to these increases. The finding that credit constraints increase the size of the output multiplier is consistent with Galí et al. (2007) and Li and Spencer (2016); and that hysteresis effects increase output multipliers is consistent with Engler and Tervala (2018). Hysteresis reduces employment multipliers marginally because higher levels of human capital translate into higher levels of output per unit of labour input, and hence slightly lower labour demand.

Table 2: Output and Employment Multipliers

		Output		Employment
Hys.	CC	CM	NPVM	CM
No	No	0.59	0.60	0.59
No	Yes	0.72	0.73	0.72
Yes	Yes	1.28	1.27	0.50

A cumulative output multiplier of 1.28 in the presence of credit constrained households and hysteresis is consistent with Auerbach and Gorodnichenko (2012a) who find cumulative output multipliers of between 1 and 1.5 during recessions in the US, and IMF (2012) findings of cumulative output multipliers associated with a positive government spending shock when output gaps are negative of 1.2 in G7 countries. Li and Spencer (2016) find a 'no monetary response' output multiplier of 1.26 during the post-GFC period in Australia in an estimated DSGE model. Our model predicts a similar multiplier without arbitrarily 'switching off' the central bank's monetary policy response function.

The interaction of credit constraints and hysteresis effects helps generate employment multipliers under half the magnitude of output multipliers in the preferred model (around 40 per cent lower). This is broadly consistent with Monacelli et al. (2010) who find cumulative unemployment multipliers of -0.43 at the two year horizon for the United States between 1954 and 2006. This translates into an employment multiplier of roughly 0.59 for the US over the period, utilising the elasticity of employment with respect to unemployment between 1948 and 2013 estimated by Ball et al. (2017) of -0.73.

Table 3 presents the welfare multipliers associated with the coordinated fiscal expansion scenario. Without hysteresis, fiscal stimulus reduces worker welfare in consumption equivalent terms consistent with Sims and Wolff (2018). However, in the model with hysteresis fiscal stimulus becomes welfare enhancing as in Engler and Tervala (2018). Rendahl (2016) derives a labour search model with nominal wage rigidity where a prolonged economic crisis accompanied by a substantial increase in government spending increases worker welfare by 0.65 dollars of private consumption for each dollar of government spending. Overall, the range of welfare multipliers reported here sits comfortably within that suggested by Rendahl (2016).

Table 3: Welfare Multipliers

		Welfare multipliers		
Hys.	CC	$\varrho = 0$	$\varrho = 0.4$	$\varrho = 1$
No	No	-0.76	-0.51	-0.01
No	Yes	-0.75	-0.50	-0.02
Yes	Yes	0.08	0.31	0.75

Table 4 contains multiplier robustness analysis for alternative parameter choices for the domestic and foreign economies. Overall, net present value output multipliers and welfare multipliers are robust to a broad range of parameter choices. Cumulative output multipliers all lie in the range of 1 to 1.5 consistent with Auerbach and Gorodnichenko (2012a). Under the baseline assumption concerning the weight of government consumption in utility $\varrho = 0.4$, the overwhelming majority of parametrisations indicate that workers are willing to sacrifice real consumption opportunities in exchange for fiscal stimulus. The Australian Government undertook fiscal consolidation in the Post-GFC period primarily though bracket creep. Murphy (2016) suggests that the marginal excess burden of bracket creep in the Australian context is around 0.18. This suggests that stimulus can be net-welfare improving under the overwhelming majority of parametrisations in the central case where $\varrho = 0.4$.

Table 4: Parameter Robustness

Parameter	Output CM	Output NPVM	Emp. CM	Welfare multipliers $\varrho = 0$	Welfare multipliers $\varrho = 0.4$	Welfare multipliers $\varrho = 1$
Baseline	1.28	1.27	0.50	0.08	0.31	0.75
$\varphi = \varphi^* = 0.5$ (1)	1.29	1.29	0.49	0.05	0.25	0.66
$\varphi = \varphi^* = 2$ (1)	1.32	1.31	0.53	0.12	0.34	0.78
$\eta = \eta^* = 0.11$ (0.2,0.13)	1.08	1.07	0.59	-0.15	0.08	0.28
$\eta = \eta^* = 0.3$ (0.2,0.13)	1.44	1.42	0.43	0.24	0.45	0.86
$\phi = \phi^* = 0.8$ (0.93,0.96)	1.03	1.02	0.56	-0.33	-0.08	0.39
$\phi = \phi^* = 0.99$ (0.93,0.96)	1.54	1.51	0.48	0.72	0.93	1.35
$\lambda = \lambda^* = 0.20$ (0.27, 0.30)	1.25	1.23	0.49	0.07	0.31	0.77
$\lambda = \lambda^* = 0.50$ (0.27, 0.30)	1.42	1.42	0.54	0.09	0.23	0.51

Output and welfare multiplier size is insensitive to different assumptions concerning the value of the Frisch elasticity of labour supply. As would be expected, higher (lower) values of the hysteresis parameters η and η^* deliver higher (lower) estimates of output, employment and welfare multipliers. Setting $\phi = 0.8$ results in significantly lower output multipliers; however, this value appears inconsistent with the mounting macroeconomic evidence regarding hysteresis effects, including that presented in this paper. Values of ϕ closer to and perhaps even including unity provide a much better match to aggregate dynamics. Finally, a lower (higher) proportion of Non-Ricardian workers generate lower (higher) output and employment multipliers as would be expected.

6 Would a change in monetary policy framework have improved outcomes?

Garga and Singh (2019) and Jordà et al. (2020) consider alternative monetary policy rules in the presence of output hysteresis. Garga and Singh (2019) find output hysteresis arises away from the ZLB where monetary policy is conducted based on the Taylor rule, but not under strict inflation-targeting. In our model the ZLB does not bind, and strict inflation-targeting offers only a minor improvement in output and employment outcomes in the domestic economy over the baseline monetary specification. This is because the weight on the output gap in the domestic economy monetary policy reaction function is already low ($\mu_2 = 0.2$). As a consequence, we do not consider strict inflation-targeting as an alternate monetary policy rule as they do.

Jordà et al. (2020) have recommended that central banks should augment standard Henderson-McKibbin-Taylor type monetary reaction functions to lean against the accumulated gaps in TFP growth generated by hysteresis. Similarly, Garga and Singh (2019) suggest that an optimal monetary policy rule should target zero output hysteresis; however only when the ZLB binds. All of the monetary policy reaction functions considered below feature this quality, in that the central bank is assumed to react to the deviation of output from its *initial* trend.

In particular, we consider three alternative simple monetary policy rules. Following the advocacy of Bernanke (2017) and Bernanke et al. (2019) for temporary PLT in the post-GFC period, and as a response to future ZLB episodes, we consider a simple PLT rule where the price level replaces annualised inflation in the central banks reaction function. In practice, this policy would make monetary policy history dependent in a manner similar to the Federal Reserve's recently announced adoption of a 'flexible form of average inflation targeting' (Powell, 2020).

Blanchard et al. (2015), Reifschneider et al. (2015) and Yellen (2016) suggested that central bank's should place a higher weight on the output gap in their reaction functions in response to hysteresis. To capture this intuition we propose two alternative simple nominal income targeting rules, a nominal GDP level targeting ('NGDPLT') rule with equal weights of 1.5 applied to the price level and output gap, and a nominal GDP growth targeting rule ('NGDPGT') which attaches the same weights to annualised inflation and output growth. We assume no change in interest rate smoothing under the alternative policy rules. In the context of the post-GFC period NGDPLT was advocated by Woodford (2012, 2013) and Sumner (2012), while McCallum (2015) has advocated for NGDPGT in preference to NGDPLT on the basis that it is 'time invariant', which is to say that it would be chosen under a monetary policy committent regime adopted in the distant past.

Table 5 sets out how output, employment and welfare multipliers vary under the alternative monetary policy rules. Overall, in response to the combined demand shocks simulated in this paper, PLT delivers the highest output, employment and welfare multipliers relative to other simple monetary policy rules considered. Welfare multipliers are higher under PLT predominantly because output is higher under the PLT rule compared to the other rules. Output and employment multipliers are lowest under NGDPLT because this rule most vigorously counteracts the positive effects of fiscal stimulus on output. Output and employment are actually substantially higher under NGDPLT compared to the other rules in the absence of fiscal stimulus. Nonetheless, output multipliers remain above one and fiscal stimulus is still welfare improving, contradicting views that NGDPLT negates the need for fiscal stimulus in response to demand driven recessions (see Sumner, 2012). Indeed, in this paper output and employment are always higher when fiscal stimulus is deployed in addition to monetary stimulus under all alternative monetary policy specifications, with and without hysteresis and credit constraints. Further when hysteresis effects are present, worker welfare is always higher in the presence of fiscal stimulus than without it, regardless of the monetary policy rule adopted.

Table 5: Multipliers under alternative simple monetary policy rules

	Output		Employment	Welfare multipliers		
Policy Rule	CM	NPVM	CM	$\varrho = 0$	$\varrho = 0.4$	$\varrho = 1$
Baseline	1.28	1.27	0.50	0.08	0.31	0.75
NGDPGT	1.30	1.28	0.51	0.09	0.32	0.75
NGDPLT	1.12	1.11	0.45	0.04	0.30	0.80
PLT	1.34	1.33	0.54	0.13	0.40	0.92

Figure 7 indicates how the dynamic response of output changes in the model with hysteresis and credit constraints based on the alternate monetary policy scenarios. PLT clearly dominates the other simple monetary policy rules in terms of output stabilisation. This is interesting given Svensson's (1999) argument that PLT should dominate inflation-targeting in terms of output and inflation stabilisation where output and employment are moderately persistent as is the case in our model. It should be stressed that this is in response to a combination of demand shocks. In the model inflation-targeting and NGDPLT rules can generate better output performance in the face of supply shocks, making the case stronger for *temporary* PLT in response to demand driven recessions, or flexible average inflation targeting more broadly.

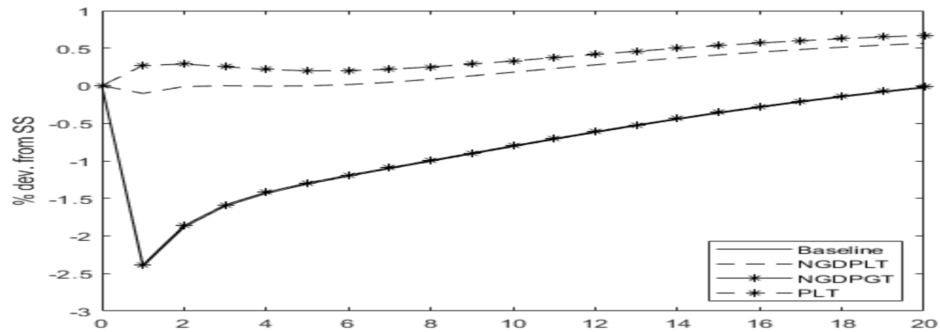

Figure 7: Dynamic response of output under alternative monetary policy (with hysteresis and credit constraints), % deviation from steady state, quarterly

Interestingly, and consistent with Garga and Singh (2019), output is higher relative to steady state the lower the weight placed on output in the monetary policy reaction function. This finding, which runs counter to the policy suggestions of Yellen (2016), Reifschneider et al. (2015) and Blanchard et al. (2015), is redolent of the Tinbergen (1952) principle that policy makers should have as many instruments at their disposal as policy targets. That is, when there are two policy targets, output and inflation stabilisation, at least two separate policy instruments are required to attain the targets. This result also implies that if central banks are trying to formalise discretion in a crisis scenario they should not opt for a variety of 'flexible inflation-targeting' that simply increases the weight afforded to output stabilisation in an inflation-targeting reaction function.

Figure 8 sets out the dynamic responses of employment under alternative monetary policy scenarios. PLT is again dominant in terms of short-run employment stabilisation compared to the other rules. However, employment outcomes converge under all alternative simple rules in the medium-term.

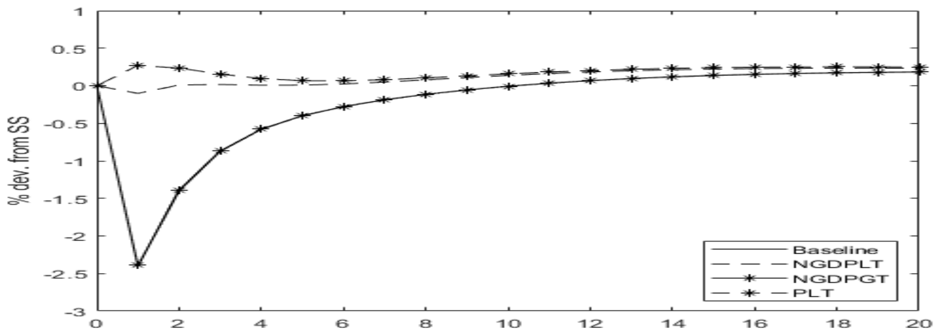

Figure 8: Dynamic response of employment under alternative monetary policy arrangements (with hysteresis and credit constraints), % deviation from steady state, quarterly

Why does PLT dominate the alternative monetary approaches in our model? Figure 9 indicates that real interest rates are persistently lower under PLT compared to the alternative simple monetary policy rules. The 'lower for longer' dimension of PLT has been emphasised by Bernanke (2017) and Bernanke et al. (2019) as a reason for supporting the adoption of temporary PLT in response to major shocks that push economies against the ZLB. This feature of PLT also explains why it outperforms an inflation-targeting rule augmented to respond to TFP growth gaps generated by hysteresis in the spirit of Jordà et al. (2020). Increasing real interest rates in response to a demand driven recession is a typical feature of inflation targeting rules in contemporary New Keynesian models. In the open economy context, the real exchange rate is also lower for longer under PLT, which enhances the benefits of PLT over alternative rules.

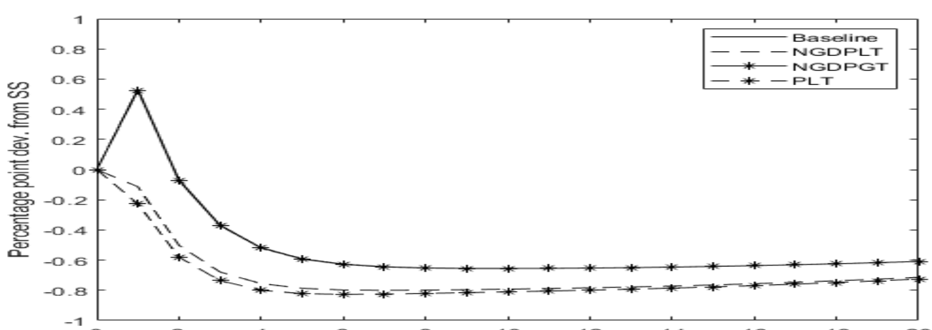

Figure 9: Dynamic response of annual domestic real interest rates ($\hat{i_t} - E_t\{\hat{\pi}_{t+1}\}$) under alternative monetary policy arrangements (with hysteresis and credit constraints), percentage point deviation from steady state, quarterly

7 Conclusion

In this paper a small open economy TANK model is simulated to assess the efficacy of fiscal stimulus in a small open economy with a floating exchange rate and inflation-targeting monetary regime. The model is closely related to the textbook New Keynesian Open Economy Model of Monacelli and Galí (2005) and Galí (2008) with a few twists. In the model a fraction of households can only consume out of their current income. Further, the production technology features a simple 'learning by doing' mechanism whereby changes in employment can persistently affect the level of productivity. We estimate model consistent parameters for the 'learning by doing' process using recent Australian data. Government is assumed to follow a balanced budget strategy, while monetary authorities follow McKibbin-Henderson-Taylor type rules.

Consistent with the evidence presented by Jordà et al. (2020), where hysteresis and credit constraints are incorporated into the model, output can remain persistently below its initial trend, whereas employment can recover to its initial steady state level within typical business cycle frequencies. Our model also generates an empirically plausible degree of hysteresis based on the evidence of Furceri at al. (2021), Kienzler and Schmid (2014), and Rawdanowicz et al. (2014). Dynamic responses of key macroeconomic variables to time preference, fiscal and monetary shocks calibrated to simulate the GFC provide a better qualitative account of the data in the medium-term compared to those derived from models without credit constrained agents or hysteresis effects.

We find that the presence of credit constraints and hysteresis effects amplifies the effectiveness of fiscal policy as a macroeconomic stabilisation tool, and helps generate fiscal multipliers consistent with estimates for advanced economies (see IMF, 2012 and Auerbach and Gorodnichenko, 2012a and 2012b in particular). Employment multipliers are just under half the magnitude of output multipliers, also consistent with recent empirical evidence. With hysteresis and credit constrained households, welfare multipliers can be positive, and output multipliers can exceed unity, even in a small open economy setting. This is because credit constraints amplify the effect of fiscal stimulus on private consumption, and the hysteresis mechanism helps counteract crowding out due to monetary offset and real exchange rate appreciation. From a policy perspective this implies that fiscal policy can be an effective macro-stabilisation tool even in the small open economy context, helping reverse hysteresis effects in productivity and output, and restore full employment more rapidly.

Our analysis shows that hysteresis strengthens the argument in favour of temporary PLT in response to a demand driven global recession, and the Federal Reserve's new approach to 'average inflation targeting'. Output, employment and welfare multipliers are higher under PLT compared to all alternative monetary policy rules. PLT also provides superior output and employment stabilisation performance compared to the baseline inflation-targeting rule, and the two alternative nominal income targeting rules, when combined with fiscal stimulus. This is because both the real interest rate and exchange rate are lower for longer under PLT compared to other rules. Further, with hysteresis there is less monetary offset of fiscal stimulus under PLT compared to the alternative rules. Under all alternative monetary policy rules output, employment and worker welfare are higher when monetary stimulus is combined with fiscal stimulus. These results reinforce the benefit of jointly considering the impact and interactions of monetary and fiscal policy, rather than addressing each arm of macroeconomic policy separately.

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