The welfare cost of macro-prudential policy in a two-country DSGE model

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Abstract

This paper builds a two-country DSGE model with financial frictions and investigates the welfare cost of macro-prudential policy and its impact on financial stability. The two countries in question are the U.S. and South Africa. The results show that macro-prudential policy results in a welfare trade-off between patient and impatient households. The impact of macro-prudential policy tends to benefit patient households more than impatient households. By decreasing the volatility of loans uptake and output growth, macro-prudential policy could helps to achieve financial stability in South Africa.

JEL codes: E32, E44, E52, E58

Keywords: Welfare cost, credit growth, macro-prudential policy, financial stability, two-country, DSGE model

1 Introduction

The business cycle bust in developed economies in 2007 was due to excessive credit growth and the housing boom (Lambertini et al., 2013; Quint and Rabanal, 2014; Brzoza-Brzezina et al., 2015). In developed countries these two factors were the result of blunt monetary and regulatory policies and large imbalances in the housing market. In those countries, shocks to credit growth caused the financial crisis and subsequent slowdown and the result was a significant imbalance of aggregates such as residential investment and housing loans. These developments reversed when the housing

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bubble burst, resulting in a decline of fiscal revenue in peripheral economies of the euro area and seriously weakening their economic stability (Brzoza-Brzezina et al., 2015). Emerging economies are not immune to large imbalances in the housing market during a housing boom, hence it is important to understand how excessive credit growth and a housing boom can be averted or moderated in emerging countries.

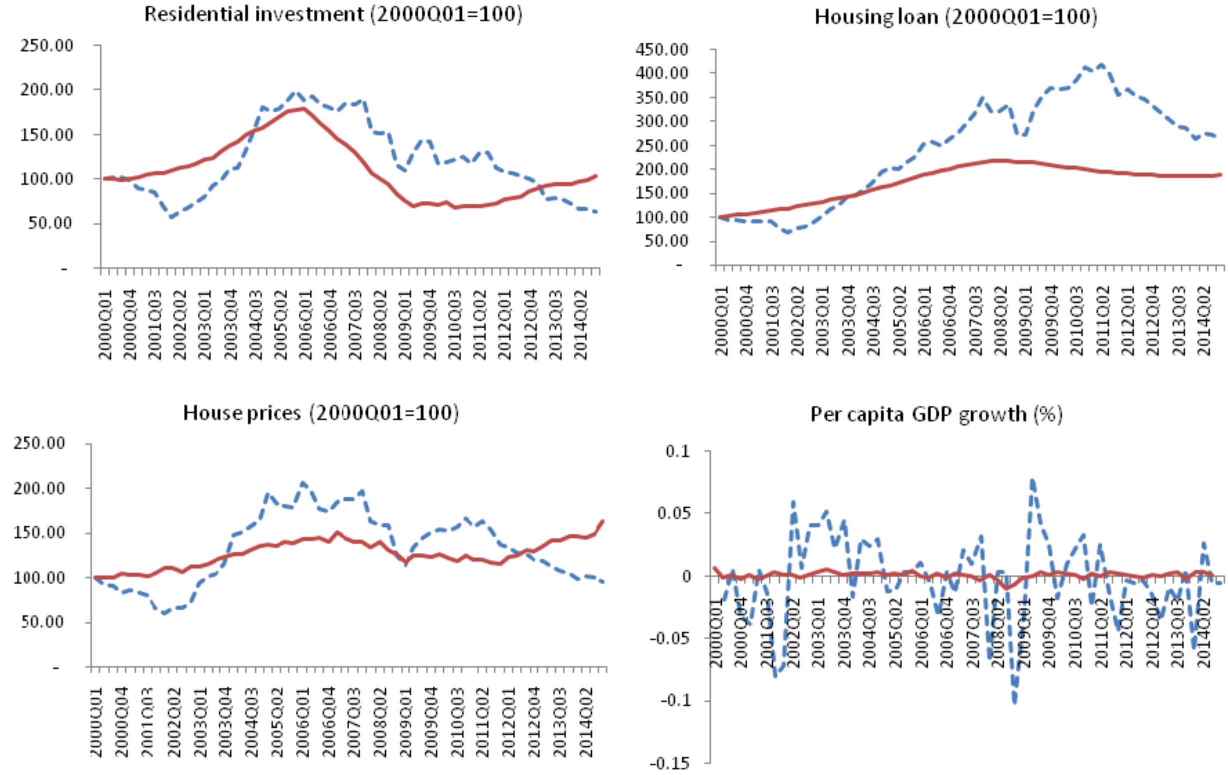
In developed countries, the excessive credit growth and housing boom have been moderated by the use of a macro-prudential policy toolkit (Claessens et al., 2013). Across developed and emerging countries, a limit on the loan-to-value (LTV) ratio is widely used, because it is effective in reducing credit growth during a boom period (Claessens et al., 2013; Lambertini et al., 2013; Quint and Rabanal, 2014; Ruboi and Carrasco-Gallego, 2014; Brzoza-Brzezina et al. 2015).

Indeed, South Africa launched formal evaluation of its financial regulation system in 2007. This was a consultative process that resulted in the publication of Financial Sector Regulation Bill that assigns the South African Reserve Bank the mandate to mitigate and ensure financial stability. It also seeks to promote coordination of policy interventions in ensuring stability of the financial sector (SARB, 2016).

Figure 1 shows the evolution of residential investments, housing loans, house prices and per capita GDP in South Africa and the U.S. for the period 2000Q01–2014Q04. All the variables are in real terms. The broken lines represent South Africa and the solid lines the U.S. The figure shows that economic aggregates were highly volatile in South Africa but relatively calm in the U.S. over the sample period. In particular, residential investment in South Africa was below that of the U.S. from 2000Q04 to 2004Q03 and from 2012Q04 to the end of the sample period. Housing prices were higher in South Africa than in the U.S. from 2003Q01 to 2008Q04 and again from 2009Q04 to the end of the sample period. South Africa experienced a boom in housing loans from 2003Q01 to 2009Q01 but in the U.S. in the same period the growth was only moderate. South Africa's GDP per capita growth over the sample period was also excessively volatile.

In this paper I investigate the implications of limiting the LTV ratio by considering the impact of such a constraint on the business cycle, financial stability, and welfare by investigating how effective macro-prudential policy is in averting or moderating excessive credit growth and housing booms in the South African business cycle over the period 1984 - 2014. To do this, I solve a two-country dynamic stochastic general equilibrium (DSGE) model with housing market frictions, following Iacoviello (2005). Similar models have also been solved in the literature by Claessens et al. (2013), Lambertini et al. (2013), Quint and Rabanal (2014), Ruboi and Carrasco-Gallego (2014) and Brzoza-Brzezina et al. (2015).

My approach, however, differs from that of Brzoza-Brzezina et al. (2015) in two important



Note: Broken line - South Africa, solid line - the U.S.

Figure 1: Differences between South Africa and the U.S., 2000Q01-2014Q04

ways. Firstly, I calibrate the structural parameters of the two-country DSGE model to South African data. Thereafter, I conduct simulations under distinct policy regimes and grade them using a welfare criterion. My results are not only applicable to South Africa but also offer insights into the effects of macro-prudential policies in other emerging economies with price and financial stability policy objectives under conditions of financial friction. Secondly, I compare conditional welfare, under tightened and loosened macro-prudential policies and optimized macro-prudential policy regimes, with a baseline policy regime.

The main findings of the paper are as follows. Macro-prudential policy results in a welfare trade-off between patient and impatient households, and the policy tends to benefit patient households more than impatient households. By decreasing the volatility of loans uptake and output growth, macro-prudential policy helps to achieve financial stability in South Africa. This is because a macro-prudential policy shock results in restrictions on borrowing thereby causing a decline in the uptake of loans by impatient households.

The rest of paper is organized as follows. The next section presents the two-country DSGE model, Section 3 outlines calibration criteria, Section 4 discusses the performance of the model, Section 5 analyzes the welfare cost of macro-prudential policy and Section 6 concludes.

2 A two-country DSGE model with financial frictions

The modeling framework is the standard two-country DSGE model following Lambertini et al. (2013), Quint and Rabanal (2014) and Brzoza-Brzezina et al. (2015). I assume that the two countries form a trading bloc with South Africa as the home country and the U.S. the foreign country. The two countries are similar in structure. Households of measure ω reside in the home country and $(1-\omega)$ in the foreign country. There are producers of consumption goods, housing and intermediate goods. Bilateral monetary policy is implemented according to a similar Taylor rule, while the macro-prudential policy instrument can be adjusted at the country level.

2.1 Households

In each country, there are two types of households indexed by $\imath$ on a unit interval and consisting of patient households $\iota \epsilon p \equiv [0, \omega_p]$ and impatient households $\iota \epsilon i \equiv [0, \omega_i]$. Variables marked with a subscript p and i refer to patient and impatient household respectively, and all other variables refer to all households.

2.1.1 Patient households

Representative patient households of measure ω_p maximize the expected lifetime utility function:

$$U_{p,t} = E_0 \left\{ \sum_{0}^{\infty} \beta_p^t \left[\begin{array}{c} e^{\varepsilon_{u,t}} \frac{(c_{p,t}(\imath) - \xi_c c_{p,t-1})^{1-\sigma_c}}{1-\sigma_c} + e^{\varepsilon_{u,t}} e^{\varepsilon_{\chi,t}} A_\chi \frac{(\chi_{p,t}(\imath) - \xi_\chi \chi_{p,t-1})^{1-\sigma_\chi}}{1-\sigma_\chi} \\ -A_n \frac{n_{p,t}(\imath)^{1+\sigma_n}}{1+\sigma_n} \end{array} \right] \right\}. \tag{1}$$

where β_p^t is the patient households' discount factor, $c_{p,t}$ is consumption and $\chi_{p,t}$ is the stock of housing. A_χ and A_n are the weights of housing and labor in utility. σ_c and σ_χ are the inverse intertemporal elasticities of substitution in consumption and housing respectively. σ_n is the inverse Frisch elasticity of labor supply $n_{p,t}$. ξ_c and ξ_χ are respectively external habit formation parameters for consumption and stock of housing. $\varepsilon_{u,t}$ and $\varepsilon_{\chi,t}$ are respectively the intertemporal preference shock and housing preference shock, both following an AR(1) process.

Patient households maximize Eq. 1 subject to a budget constraint specified as:

$$\begin{aligned} & P_t c_{p,t}(\imath) + P_{\chi,t}(\chi_{p,t}(\imath) - (1-\delta_\chi)\chi_{p,t-1}(\imath)) + D_{p,t}(\imath) = \{W_{p,t}(\imath) n_{p,t}(\imath) \\ & + R_{k,t} k_p(\imath) + R_{t-1} D_{p,t-1}(\imath) + \Pi_{p,t}(\imath)\}. \end{aligned} \tag{2}$$

where P_t is the relative price of consumption goods. $P_{\chi,t}$ is the price of housing. $W_{p,t}$ is the patient households' nominal wage. δ_χ is the housing stock depreciation rate. $D_{p,t}$ is the patient households' savings in the banking sector earning a risk-free rate R_t. The model assumes that the patient households own physical capital k_p which they rent at rate $R_{k,t}$ to all firms and banks in the economy. $\Pi_{p,t}$ is dividends earned from firms and banks.

Letting $\lambda^p_{c,t}$ be the Lagrange multiplier associated with the budget constraint, I obtain the patient households' first-order conditions as follows:

$$\lambda^p_{c,t} = \frac{-\sigma_c}{1-\xi_c}\left(c_{p,t}(\imath) - \xi_c c_{p,t-1}\right) + \varepsilon_{u,c}, \tag{3}$$

$$\lambda^p_{c,t} = E_t u^p_{c,t+1} + R_{D,t} - E_t\pi_{t+1}, \tag{4}$$

$$\sigma_\chi \chi_{p,t} = u^p_{c,t} - P_{\chi,t} + \frac{\beta^t_p(1-\delta_\chi)}{1-\beta^t_p(1-\delta_\chi)}\left(E_t\pi_{\chi,t+1} - R_{D,t}\right) + \varepsilon_{u,c}\varepsilon_{\chi,c}A_\chi, \tag{5}$$

$$w_t = A_n\frac{{n_{p,t}}^{\sigma_n}}{c_{p,t}}. \tag{6}$$

Eq. 3 is the patient households' marginal utility, Eq. 4 is their Euler equation, Eq. 5 is their holding of housing, and Eq. 6 is the real wage equation.

2.1.2 Impatient households

Impatient households of measure $(1-\omega_p)$ optimize by choosing consumption $c_{i,t}$, housing $\chi_{i,t}$ and labor supply $n_{i,t}$. They maximize the same utility function (Eq. 1) as patient households and discount the future more heavily, that is $\beta^t_i \prec \beta^t_p$.

Subject to the budget constraint:

$$P_t c_{i,t}(\imath) + P_{\chi,t}\left(\chi_{i,t}(\imath) - (1-\delta_\chi)\chi_{i,t-1}(\imath)\right) + R_{L,t-1}L_{i,t-1}(\imath) \le W_{i,t}(\imath)\, n_{i,t}(\imath) + L_{i,t}(\imath). \tag{7}$$

where $L_{i,t}$ is the amount of credit accessed by impatient households. $W_{i,t}$ is the impatient households' nominal wage.

Impatient households also face a borrowing constraint specified as:

$$R_{L,t}L_{i,t}(\imath) \le m_{\chi,t}E\left\{P_{\chi,t-1}\right\}(1-\delta_\chi)\,\chi_{i,t}(\imath). \tag{8}$$

where $m_{\chi,t}$ is the LTV ratio set by the macro-prudential authority and $R_{L,t}$ is the interest rate on loans.

Letting $\lambda^i_{c,t}$ be the Lagrange multiplier associated with the budget constraint, I obtain the impatient households' first-order conditions as follows:

$$\lambda^i_{c,t} = \frac{-\sigma_c}{1-\xi_c}\left(c_{i,t}(\imath) - \xi_c c_{i,t-1}\right) + \varepsilon_{u,c}, \tag{9}$$

$$\left[1 - \beta_i^t\left(1-\delta_\chi\right) + \left(\beta_i^t - \frac{\pi}{\overline{R}_L}\right)\overline{m}_\chi\right]\left(\xi_\chi - \sigma_\chi \chi_{i,t}\right) = \lambda^i_{c,t} - P_{\chi,t} + m_\chi \beta_i^t E_t \lambda^i_{c,t+1} + \Lambda, \tag{10}$$

where

$\Lambda \equiv \{\left(\beta_i^t - \frac{\pi}{\overline{R}_L}\right)\overline{m}_\chi\left(E_t P_{\chi,t+1} + m_{\chi,t}\right) - \overline{m}_\chi \frac{\pi}{\overline{R}_L}\left(E_t \pi_{\chi,t+1} + \lambda^i_{c,t} - R_{L,t}\right)$
$- \left(1-\delta_\chi\right)\beta_i^t\left(E_t\lambda^i_{c,t+1} + E_t P_{\chi,t+1}\right) + \varepsilon_{u,c}\varepsilon_{\chi,c}A_\chi\}.$

$$w_t = A_n \frac{{n_{i,t}}^{\sigma_n}}{c_{i,t}}. \tag{11}$$

Eq. 9 is the patient households' marginal utility, Eq. 10 is their holding of housing, and Eq. 11 is the real wage equation.

2.1.3 Labor supply

Patient and impatient households supply monopolistically different labor services to competitive aggregators that convert them into a single labor input specified as:

$$n_t = \left[\omega_p n_{p,t}^{\frac{\phi_n - 1}{\phi_n}} + \omega_i n_{i,t}^{\frac{\phi_n - 1}{\phi_n}}\right]^{\frac{\phi_n}{\phi_n - 1}}. \tag{12}$$

where $n_{p,t} = \left[\int_0^1 n_{p,t}(\imath)^{\frac{1}{\mu_w}}\, d\imath\right]^{\mu_w}$, $n_{i,t} = \left[\int_0^1 n_{i,t}(\imath)^{\frac{1}{\mu_w}}\, d\imath\right]^{\mu_w}$. ϕ_n is the elasticity of substitution between labor supplied by patient and impatient households. μ_w is the elasticity of substitution between distinct labor varieties.

In the model I assume, firstly, that wages are sticky for both patient and impatient households. This implies that, in each period with probability $1-\theta_w$, each household obtains a Calvo hint to re-optimize their wages. If not optimized, wages are indexed according to $\pi_{\zeta_w,t} = \pi_{\zeta_w,t-1} + (1-\zeta_w)\pi$, where, $\pi_t \equiv P_t/P_{t-1}$ and π represent inflation and its equilibrium level, respectively, whereas ζ_w governs the degree of wage indexation to previous inflation (Brzoza-Brzezina et al., 2015). Secondly, I assume that there is perfect risk sharing across patient and impatient households. This implies that wage stickiness does not generate further differences in consumption and housing preferences between patient and impatient households.

2.2 Producers

The model economy consists of consumer goods producers, housing goods producers and intermediate goods producers. All the producers are owned by patient households.

2.2.1 Consumption goods producers

Perfectly competitive consumption goods producers purchase domestic and foreign ranges of differentiated intermediate goods $c_{H,t}(i)$ and $c_{F,t}(i)$ to produce identical goods as per technology function specified as:

$$c_t = \left((1 - \eta_H)^{\frac{1}{\phi_c}} c_{F,t}^{\frac{\phi_c - 1}{\phi_c}} + \eta_H^{\frac{1}{\phi_c}} c_{H,t}^{\frac{\phi_C - 1}{\phi_c}} \right)^{\frac{\phi_c}{\phi_c - 1}}. \tag{13}$$

where $c_{F,t} = \left(\int_0^1 c_{F,t}(i)^{\frac{1}{\mu}} di \right)^{\mu}$, $c_{H,t} = \left(\int_0^1 c_{H,t}(i)^{\frac{1}{\mu}} di \right)^{\mu}$. η_H is the degree of home bias in consumption. ϕ_c is the elasticity of substitution between domestic and foreign consumption goods. μ is the elasticity of substitution between differentiated intermediate goods.

2.2.2 Housing goods producers

Perfectly competitive housing goods producers in period t purchase un-depreciated housing from the previous period and produce new housing stock specified as:

$$\chi_t = (1 - \delta)\chi_{t-1} + \varepsilon_{I\chi,t} \left(1 - S_\chi \left(\frac{I_{\chi,t}}{I_{\chi,t-1}} \right) \right) I_{\chi,t}. \tag{14}$$

where housing investment $I_{\chi,t} = \left(\int_0^1 I_{\chi,t}(I)^{\frac{1}{\mu}} di \right)^{\mu}$ is produced using domestic intermediate inputs. $\varepsilon_{I\chi,t}$ is an AR(1) housing investment specific technology shock.

Housing goods producers also face a housing investment adjustment cost $S_\chi(\frac{I_{\chi,t}}{I_{\chi,t-1}}) = \frac{\kappa_\chi}{2} \left(\frac{I_{\chi,t}}{I_{\chi,t-1}} - 1 \right)^2$ where $\kappa_\chi \succ 0$ is the degree of nominal price rigidity and determines the size of the housing investment adjustment cost.

2.2.3 Intermediate goods producers

Intermediate goods producers q hire labor and capital to produce differentiated goods using a production technology function expressed as;

$$c_{H,t}(q) + \frac{1 - \omega}{\omega} c_{H,t}^*(q) + I_{\chi,t}(q) = z_t k(q)^{\alpha} n_t(q)^{1-\alpha}. \tag{15}$$

where z_t is the productivity shock following an AR(1) process. Each intermediate goods producer i works in a monopolistically competitive environment with a probability of $(1-\theta)$ to set its price in line with the Calvo format. If not, wages are indexed according to $\pi_{\zeta,t} = \pi_{\zeta,t-1} + (1-\zeta)\,\pi$, where, ζ_w governs the degree of wage indexation to previous inflation (Brzoza-Brzezina et al., 2015).

2.3 Banks

A range of monopolistically competitive banks j supply loans to impatient households. The loans are refinanced firstly by using deposits D_t received from patient households at rate R_t and secondly by borrowing $\widetilde{D}_t^*$ from the foreign interbank market at the rate $\rho_t R_t^*$.

Representative banks in the home country maximize:

$$E_0 \left\{ \beta_p \frac{u_{p,t+1}}{P_{t+1}} \left[R_{L,t}\,(j)\, L_t\,(j) \right] - R_t D_t\,(j) - S_{t+1} \rho_t R_t^* \widetilde{D}_t^*\,(j) \right\}. \tag{16}$$

where $u_{p,t}$ is the marginal utility of the patient households' real income. ρ_t is a risk premium growing at $\rho_t = 1 + \xi(\exp(d_t - d) - 1)$ in which d_t is the debt-to-GDP ratio of the home country and d is its steady state level.

Eq. 16 is subject to a flow of funds constraint:

$$L_t\,(j) = D_t\,(j) + S_t \widetilde{D}_t^*\,(j)\,. \tag{17}$$

and the demand for loans entails a Dixit-Stiglitz loan aggregator:

$$\omega_I L_{I,t} = \left(\int_0^1 L_t\,(j)^{\frac{1}{\mu_L}}\, dj \right)^{\mu_L}. \tag{18}$$

2.4 Closing the model

2.4.1 GDP and balance of payments

The aggregate output (GDP) is specified as:

$$y_t \equiv c_{H,t} + c_{H,t}^* \frac{1-\omega}{\omega} + I_{\chi,t}. \tag{19}$$

The law of motion of the home country's net foreign debt $\widetilde{D}_t^*$ is specified as;

$$\widetilde{D}_t^* = P_{F,t} c_{F,t} - \frac{1-\omega}{\omega} P_{H,t}^* c_{H,t}^* + \varrho_{t-1} R_{t-1}^* \widetilde{D}_{t-1}^*. \tag{20}$$

where $P_{H,t}^*$ and $P_{F,t}$ are the prices of the home country's exports and imports respectively.

Total hours worked is equal to the aggregate supply of labor. The labor market clears as follows:

$$n_t = \omega_p n_{p,t} + \omega_i n_{i,t}. \tag{21}$$

The housing market clears as follows:

$$\beta_p^t \chi_{p,t} + \beta_i^t \chi_{i,t} = \chi_{t-1}. \tag{22}$$

The intermediate goods market clears as follows:

$$\int_0^1 c_{H,t}(q)\, dq + c_{H,t}^*(q)\, dq = y_t. \tag{23}$$

2.4.2 Monetary policy

The monetary authority sets an identical monetary policy rate following a standard Taylor rule specified as:

$$\frac{R_t^*}{R^*} = \left(\frac{R_{t-1}^*}{R^*}\right)^{\gamma_R^*} \left[\left(\frac{\widetilde{\pi}_t}{\widetilde{\pi}^*}\right)^{\gamma_\pi^*} \left(\frac{\widetilde{y}_t}{\widetilde{y}}\right)^{\gamma_y^*}\right]^{1-\gamma_R^*} e^{\varepsilon_{R,t}^*}. \tag{24}$$

where $\widetilde{y}_t \equiv \omega y_t + (1-\omega)\, y_t^*$ and $\widetilde{\pi}_t \equiv (\pi_t)^{\omega} (\pi_t^*)^{(1-\omega)}$. γ_π^* and γ_y^* are policy rate responses to inflation and output respectively. γ_R^* is the degree of interest rate smoothing. $\varepsilon_{R,t}^*$ is an i.i.d. monetary policy shock. Variables without a time subscript denote their respective steady state values.

2.4.3 Macro-prudential policy

Macro-prudential authorities in the home country and the foreign country act independently and set a country specific macro-prudential policy using an LTV ratio instrument following a reaction rule specified as:

$$\frac{m_{\chi,t}}{m_\chi} = \left(\frac{l_t}{l}\right)^{\gamma_{ml}} \left(\frac{p_{\chi,t}}{p_\chi}\right)^{\gamma_{mp}} \left(\frac{y_t}{y}\right)^{\gamma_{my}}. \tag{25}$$

where $\gamma_{ml}, \gamma_{mp}, \gamma_{my}$ are the sizes of instrument reaction to percentage deviations on loans, house prices and output respectively, from their respective steady state values.

3 Solving the model

The model parameters are calibrated to values that are appropriate for the South African economy, by computing the averages of quarterly time series data for the period 1984 - 2014, before the solution is derived. The impulse response functions are then generated with the aid of a stochastic simulation. The data sources are described in the Appendix B. The data is transformed by taking logarithms of per capita values of the variables and is utilized in computing the steady state ratios and the second moments implied by the data. In my calibration, South Africa represents the home country and the U.S. the foreign country. I assume that the home country has stabilization problems owing to asymmetric shocks to the two countries, that the two countries are structurally the same, and that the only difference between them is the degree of shock encountered. Tables 1 and 2 show steady state ratios and the calibrated parameters respectively.

Table 1: Steady state ratios

Steady state ratio	Value
Import to output ratio (home country)	0.23
Import to output ratio (foreign country)	0.20
Residential investment to output ratio	0.02
Capital to output ratio (annual)	2
Hours worked	0.33
Housing wealth to output ratio (annual)	0.02
Debt to output ratio (annual)	0.25
Spread (annualized)	0.019
Relative consumption of impatient households	0.75

4 Performance of the model

In this section I present the performance of the two-country DSGE model. I analyze the dynamics of the second moments, the variance decomposition and the impulse response functions. I compare the performance of the model under a common macro-prudential policy regime jointly implemented by the home and foreign countries with its performance under an independent macro-prudential policy regime implemented autonomously by the home and foreign countries.

4.1 Second moments

Table 3 compares the second moments of the two-country DSGE model (simulated under common monetary policy and independent macro-prudential policy) with those implied by the data. The data show that house prices are the most volatile variable, followed by mortgage interest rate, residential investment, mortgage loans, and lastly consumption. The two-country DSGE model

Table 2: Calibrated parameters

Parameter	Description	Value
β_p, β_p^*	Discount factor, patient households	0.90
β_i, β_i^*	Discount factor, impatient households	0.87
$\delta_\chi, \delta_\chi^*$	Housing stock depreciation	0.02
ω_i, ω_i^*	Share of impatient households	0.5
A_χ, A_χ^*	Weight on housing utility	2.43
A_n, A_n^*	Weight on labor in utility	255
σ_c, σ_c^*	Inverse of intertemporal elasticity of substitution in consumption	1
$\sigma_\chi, \sigma_\chi^*$	Inverse of Frisch elasticity of labor supply	1
σ_n, σ_n^*	Inverse of intertemporal substitution of housing	1
ξ_c, ξ_c^*	Degree of external habit formation in consumption	0.54
ξ_χ, ξ_χ^*	Degree of external habit formation in housing	0.03
θ_w, θ_w^*	Calvo probability for wages	0.75
ζ_w, ζ_w^*	Indexation parameter for wages	0.5
μ_w, μ_w^*	Steady state labor markup	1.2
ϕ_n, ϕ_n^*	Elasticity of substitution between patient and impatient labor	6
t, t^*	Real transfers from patient to impatient households	0.25
μ, μ^*	Steady state product markup	1.2
θ_H, θ_F^*	Calvo probability for domestic prices	0.9
θ_F, θ_H^*	Calvo probability for export prices	0.75
$\zeta_H, \zeta_F^*, \zeta_H^*, \zeta_F^*$	Indexation parameter for prices	0.5
α, α^*	Output elasticity with respect to physical capital	0.3
k, k^*	Physical capital stock per capita	6.5
$\kappa_\chi, \kappa_\chi^*$	Housing investment adjustment cost	30
μ_L, μ_L^*	Loan markup	0.5
m_χ, m_χ^*	Steady state LTV ratio	0.75
π, π^*	Steady state inflation	1.005
ξ	Elasticity of risk premium with respect to foreign debt	0.001
γ_R	Interest rate smoothing in Taylor rule	0.9
γ_π	Response to inflation in Taylor rule	2
γ_y	Response to output in Taylor rule	0.15
γ_{ml}	Size of instrument reaction to percentage deviation on loans	1
γ_{mp}	Size of instrument reaction to percentage deviation on house prices	0
γ_{my}	Size of instrument reaction to percentage deviation on output	0
ω	Share of home to foreign economy	0.27
η_c	Share of domestic goods in consumption basket (home economy)	0.36
$\eta_c^* = \frac{\omega(1-\eta_c)}{(1-\omega)}$	Share of goods in consumption basket (foreign country)	0.18
ϕ_c, ϕ_c^*	Elasticity of substitution between home and foreign goods	0.591

underestimates consumption (1.75), residential investment (1.13), house prices (0.02), mortgage interest rate (0.00) and inflation (0.00), but tends to overestimate mortgage loans (3.91). Similar results are obtained when the two-country DSGE model is simulated under the bilateral monetary policy and the common macro-prudential policy. The underestimated variables are, however, consistent with the findings of Gruss and Sgherri (2009), who report that the introduction of a policy intervention, such as LTV limits, that reduces the procyclicality of credit, makes it possible to dampen the volatility of macroeconomic aggregates for Estonia and Sweden. This is also in line with findings by Gelain et al. (2013) for the U.S. and by Falagiarda and Saia (2013) and Brzoza-Brzezina et al. (2015) on the implementation of Basel III for the euro area.

Table 3: Second moments, South Africa and the U.S. 1984-2014

Shock/Variable	Consumption	Residential investment	Mortgage loans	House prices	Mortgage interest rate	Inflation
Standard deviation						
Data	1.69	5.64	2.20	7.45	5.81	0.36
	(0.06)	(0.02)	(0.07)	(0.02)	(0.06)	(0.01)
Model	1.75	1.13	3.91	0.02	0.00	0.00
Correlation with consumption						
Data	1.00	0.65	0.08	0.87	−0.01	−0.29
	(0.00)	(0.02)	(0.04)	(0.00)	(0.06)	(0.00)
Model	1.00	0.04	0.50	0.52	−0.51	0.10
Autocorrelation						
Data	0.12	0.60	0.92	0.50	0.01	0.57
	(0.05)	(0.01)	(0.07)	(0.02)	(0.06)	(0.00)
Model	0.93	0.99	0.61	0.86	0.87	0.91

Note: In parentheses, standard errors.

The correlation of consumption with residential investment, mortgage loans and housing prices is positive in the data, but the correlation of consumption with mortgage interest rate and inflation is negative. The two-country DSGE model shows a positive correlation of consumption with residential investment, mortgage loans, house prices and inflation and a negative correlation with mortgage interest rate. This result is consistent with the findings in the literature. For instance, Brzoza-Brzezina et al. (2015) find that there is a positive correlation of consumption with residential investment, housing prices and mortgage loans and a negative correlation of consumption with mortgage interest rate and inflation for the euro area.

The data show a significant positive autocorrelation of consumption, residential investment, mortgage loans, house prices, mortgage interest rate and inflation. The two-country DSGE model reproduces a positive serial correlation of all the variables. According to Gelain et al. (2013), the larger persistence enhances the two-country DSGE model's ability to generate the large swings in macroeconomic variables observed in many developed economies in recent years.

4.2 Variance decomposition

Table 4 shows the variance decomposition predicted by the two-country DSGE model in both the foreign and the home country. The results show that fluctuations in consumption are mainly driven by preference shock. This is consistent with Bailliu et al. (2015), whose estimation results show that preference shock is the most persistent and volatile shock and the main source of fluctuations in output and consumption. Investment specific shock is the main driver of fluctuations in residential investment and house prices, as also argued by Bailliu et al. (2015). Variations in mortgage loans and the mortgage interest rate are driven mainly by monetary policy shock in the foreign country and mainly by foreign policy shock in the home country. In the foreign country productivity shock plays an important role in explaining fluctuations in inflation, whereas in the home country foreign policy shock plays this role. Housing preference shock plays only a small role in explaining the fluctuations in all the variables. Similar results are again obtained when the two-country DSGE model is simulated under a bilateral monetary policy and a common macro-prudential policy. The result is largely consistent with findings by Brzoza-Brzezina et al. (2015), except for fluctuations in residential investment in both the foreign and the home countries, and variations in mortgage interest rate in the foreign country.

4.3 Impulse responses

In this subsection I present the impulse response of selected variables to shocks in the two-country DSGE model. In each figure the x-axis shows periods after the shock and the y-axis shows the percentage variation of each variable from its equilibrium value.

Figure 2 shows the impulse responses to a negative shock to the LTV ratio. The figure shows that tightening of borrowing conditions due to the negative LTV ratio shock results in a decline in uptake of loan by impatient households. Thus, impatient households reduce their consumption levels and residential investment and in turn output falls. A decrease in the demand for residential investment lowers house prices. Although the interest rate rises, it hardly stabilizes the economy.

Figure 3 shows the responses to a positive investment specific shock. The figure shows that the shock causes residential investment to increase because of a higher rate of return on the current stock of housing. This in turn influences households to delay consumption and causes a rise in output because of higher efficiency in converting final goods into investment goods. As residential investment increases, house prices fall, and the balance sheet position for firms is weakened, causing a decline in consumption and in uptake of loans.

Figure 4 shows the responses to a positive housing preference shock. It shows that the shock

Table 4: Variance decomposition

Shock/Variable	Consumption	Residential investment	Mortgage loans	House prices	Mortgage interest rate	Inflation
Productivity						
Foreign country	4.08	35.85	1.00	4.62	28.69	46.90
Home country	3.79	34.02	0.62	3.27	17.65	29.79
Preference						
Foreign country	58.80	0.65	4.51	2.39	0.86	1.02
Home country	56.19	1.14	2.39	3.26	0.36	0.97
Housing preference						
Foreign country	2.90	8.91	6.54	5.79	0.04	0.08
Home country	2.41	8.42	3.42	5.97	0.02	0.03
Investment specific						
Foreign country	4.89	49.04	25.26	58.45	3.33	0.82
Home country	3.36	49.03	10.84	53.22	1.94	0.66
Monetary						
Foreign country	24.63	2.16	59.28	20.78	47.50	20.88
Foreign						
Home country	29.49	7.28	30.20	33.12	79.90	68.49

leads to an increase in output, residential investment and house prices. The rise in house prices implies higher collateral value, hence borrowers are able to access more loans. However, the shock raises consumption by a small degree. A low interest rate reduces the increase in house prices.

Figure 5 shows the response of key variables in the model following a positive productivity shock. The figure shows that output, consumption, residential investment and house prices initially decrease before increasing, while inflation and loans decrease. A positive productivity shock in the housing market results in an increase in housing investment, induced by low construction costs, causing a slump in house prices. This is because in the wake of a positive productivity shock, intermediate goods producers invest more and the demand for capital rises.

The impulse response functions presented above are consistent with the findings by Quint and Rabanal (2014), Ruboi and Carrasco-Gallego (2014) and Brzoza-Brzezina et al. (2015), for developed countries.

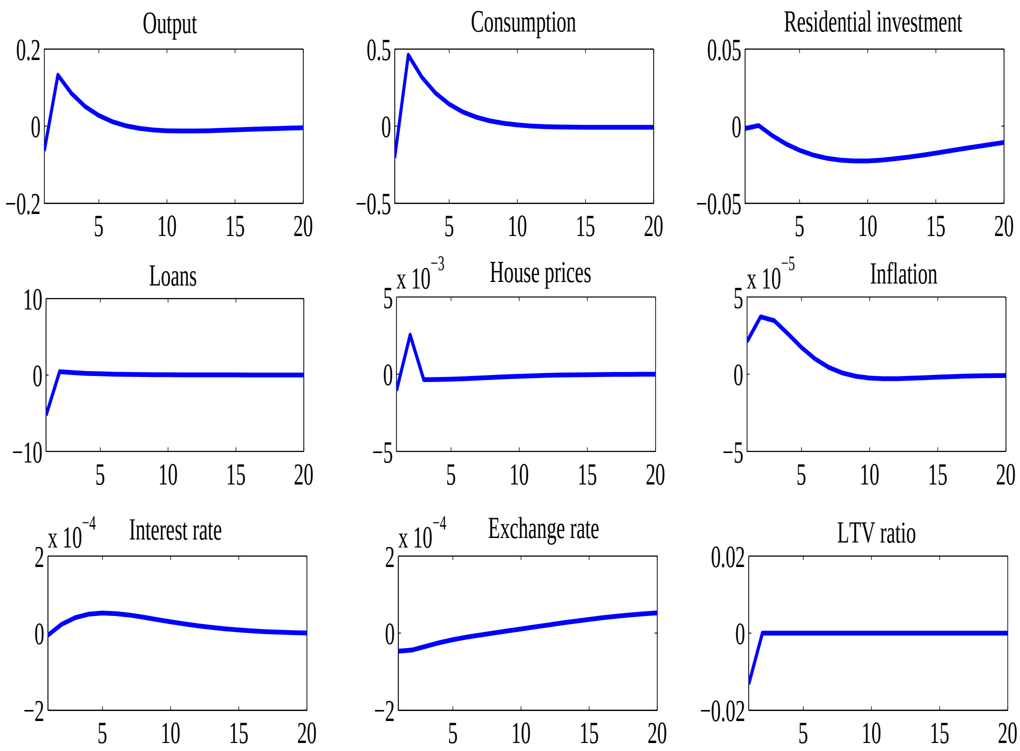


Figure 2: Impulse responses to a macro-prudential policy shock

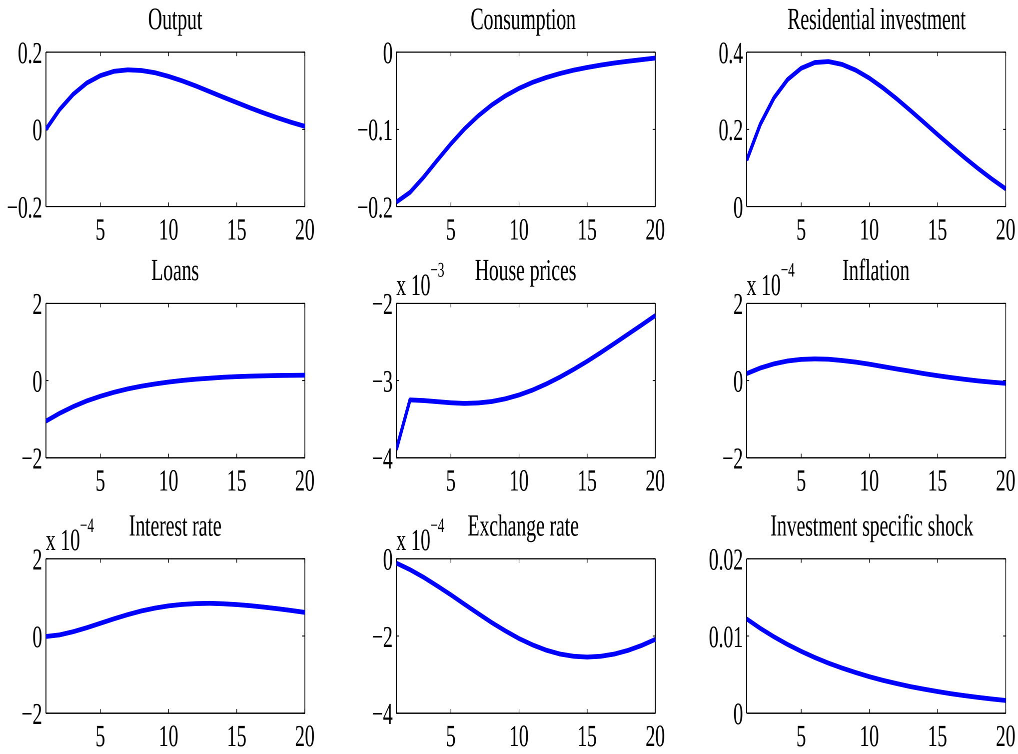


Figure 3: Impulse responses to an investment specific shock

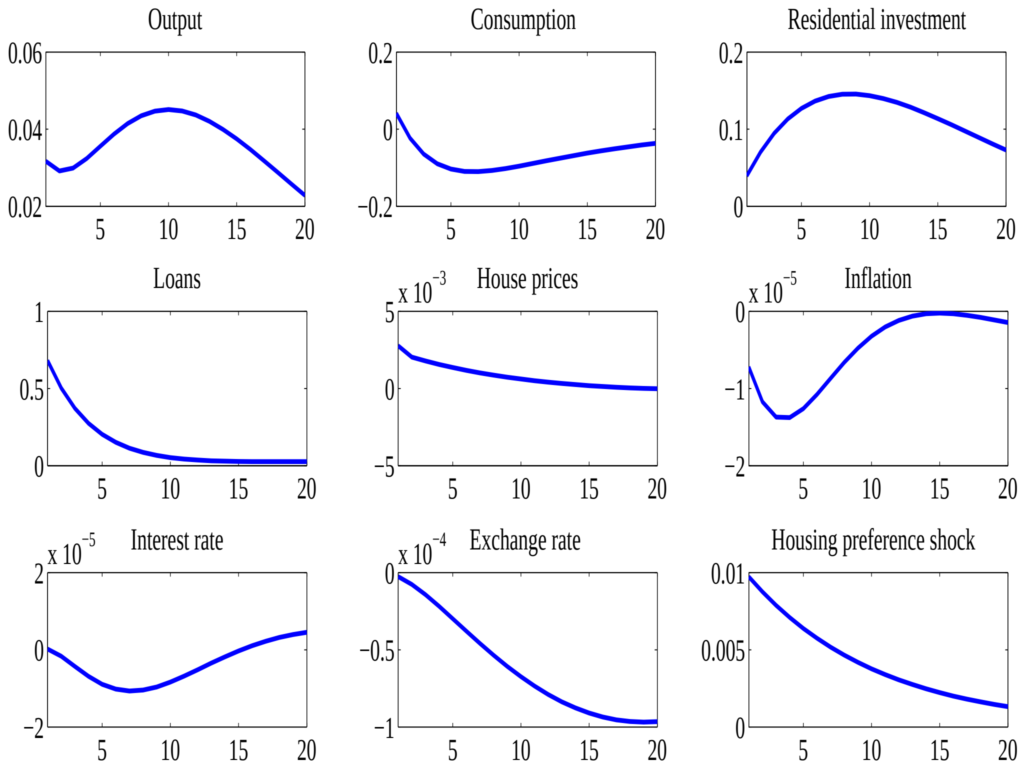


Figure 4: Impulse responses to a housing preference shock

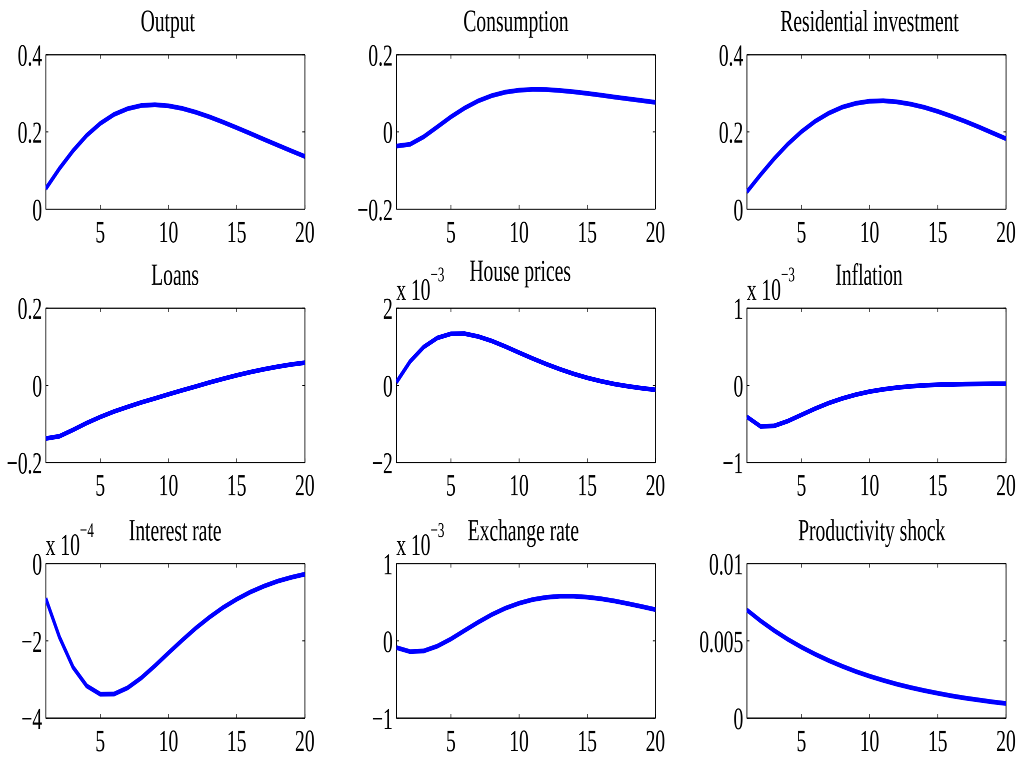


Figure 5: Impulse responses to a productivity shock

5 The welfare cost of macro-prudential policy

The welfare cost of macro-prudential policy is measured using numerical methods. The two-country DSGE model assumes that the policymaker's objective function is to maximize patient and impatient households' utility. Following Rubio and Carrasco-Gallego (2014) and Brzoza-Brzezina et al. (2015), the policymaker maximizes the aggregate social welfare of patient and impatient households. This aggregate social welfare is weighted by their respective discount factors, such that each set of households receives the same level of utility from a constant consumption structure, and is given by:

$$\omega_P \left(1 - \beta_P\right) U_{P,t} + \omega_I \left(1 - \beta_I\right) U_{I,t}. \tag{26}$$

Changes in welfare are presented in terms of consumption equivalent units that denote the percentage of consumption households would be willing to forgo in order to benefit from a macro-prudential policy intervention. A positive value implies welfare improvement. As its baseline, the two-country DSGE model uses welfare evaluated when macro-prudential policy is dormant and compares it with welfare when macro-prudential policy is activated.

Figures 6 and 7 show welfare gains from independent and common macro-prudential policy, given different values of the LTV ratio, relative to a baseline macro-prudential policy. The results show that there is a Pareto optimal macro-prudential policy up to an LTV ratio of 0.5. However, as the LTV ratio rises above a value of 0.5, there is a welfare trade-off between patient and impatient households. In particular, the results from a welfare analysis of the two-country DSGE model show that patient households' welfare improves while impatient households' welfare declines. This trend is consistent with Rubio and Carrasco-Gallego's findings (2014) for a closed economy. As argued by Campbell and Hercourtz (2009), the welfare trade-off between patient and impatient households is due not to the direct effects on welfare, but to small changes in the LTV ratio parameter, which has strong effects on borrowing collateral constraint, resulting in large changes in borrowing and hence the welfare trade-off.

I also compare the performance of the model under three policy regimes: the baseline policy regime, which is a standard Taylor rule responding to inflation and output with an interest rate smoothing parameter and is applied in the home country, and the common and the independent macro-prudential policies discussed in Section 4.

Table 5 shows conditional welfare under a tightened macro-prudential policy, $m_\chi = 0.75$, and a loosened macro-prudential policy, $m_\chi = 0.25$, under all shocks. The table shows that total welfare value under an LTV ratio of 0.75 is -3,436.73 and under an LTV ratio of 0.25 it is -3,436.05.

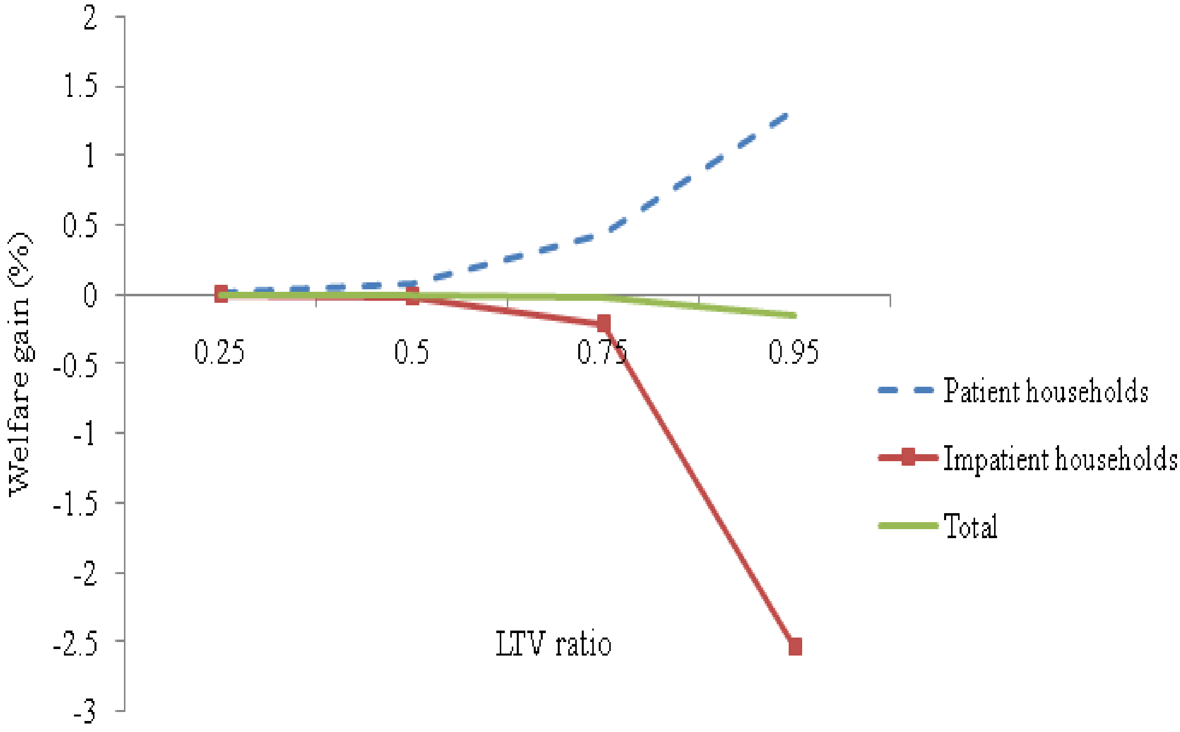


Figure 6: Welfare gains from increasing LTV ratio - independent macro-prudential policy

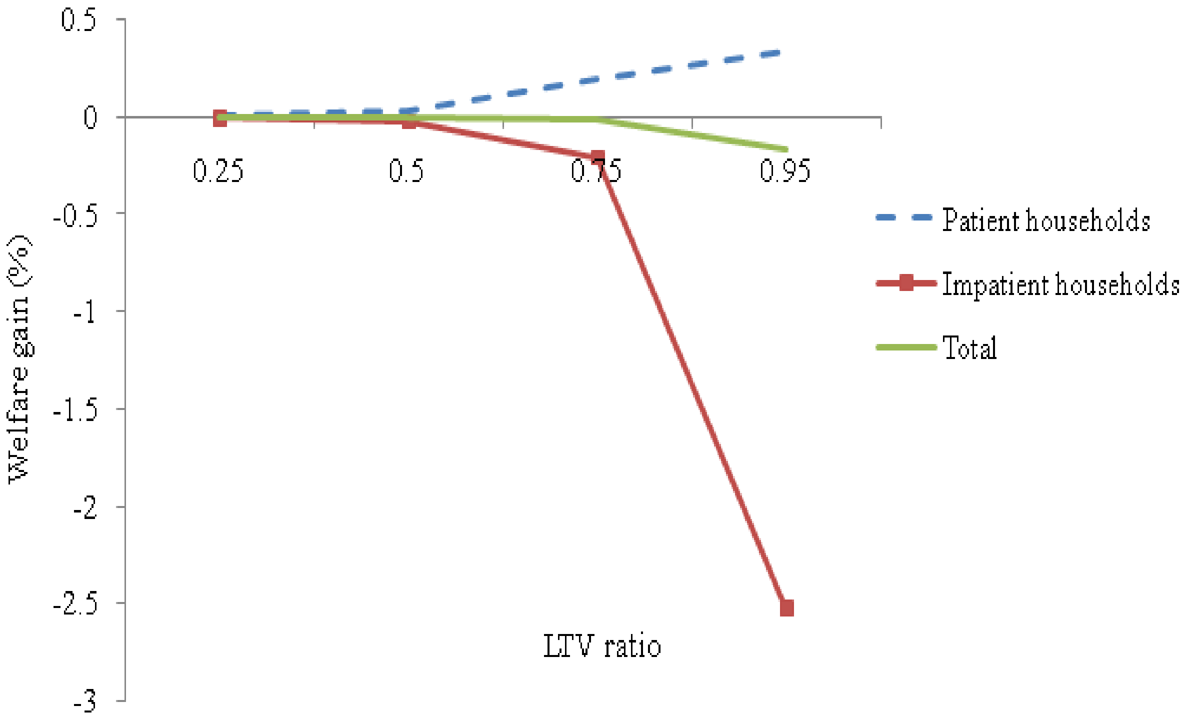


Figure 7: Welfare gains from increasing LTV ratio - common macro-prudential policy

The table also shows that independently implemented macro-prudential policy improves patient households' welfare. However, neither the common nor the independent macro-prudential policy constitutes Pareto improvement because only patient households benefit. The trade-off finding between patient and impatient households is consistent with Lambertini et al.'s finding (2013) that an LTV regime that focuses on either output growth or house price growth results in a welfare trade-off between the two types of household. The welfare trade-off is due to the connection of patient and impatient households in the credit market. That is, the LTV ratio affects lending to impatient households, by reducing patient households' savings. For instance, since the incomes of patient and impatient households are positively correlated, any attempt to smooth the consumption of one group usually comes at the cost of distorting that of the other.

Table 5: Conditional welfare under tightened and loosened regimes

	Welfare values		
Regimes	Total	Patient HHs	Impatient HHs
Tightened macro-prudential policy, $m_\chi = 0.75$			
Baseline policy	$-3,436.73$	$-343,583.19$	$-26,427.84$
Common macro-prudential policy	$-3,435.75$	$-343,582.88$	$-26,428.21$
	(-0.02)	(0.31)	(-0.37)
Independent macro-prudential	$-3,435.75$	$-343,582.47$	$-26,428.21$
	(-0.02)	(0.72)	(-0.38)
Loosened macro-prudential policy, $m_\chi = 0.25$			
Baseline policy	$-3,436.05$	$-343,665.55$	$-26,426.46$
Common macro-prudential policy	$-3,436.05$	$-343,665.54$	$-26,426.48$
	(-0.00)	(0.01)	(-0.03)
Independent macro-prudential policy	$-3,436.05$	$-343,665.46$	$-26,426.49$
	(-0.00)	(0.09)	(-0.03)

Note: In parentheses, individual welfare gain/losses with respect to the baseline policy.

Table 6 shows conditional welfare under optimized regimes. It displays the parameters of each regime that optimizes total households' welfare. In the table, coefficients of $\gamma_{my} = 0, \gamma_{ml} = 0$, and $\gamma_{mp} = 0$ apply in the cases where the LTV ratio does not respond to output, loans and house prices respectively and macro-prudential policy is dormant. It also shows that the total welfare value and the welfare values of patient and impatient households are higher under the common and independent macro-prudential policies than under the baseline policy. The table clearly shows that across all the regimes there is a trade-off between patient and impatient households, except when the optimized regime responds to house prices and the macro-prudential policy is conducted independently, resulting in welfare loses for both patient and impatient households. My analysis shows that patient households achieve the largest welfare value and this is obtained when macro-prudential policy is conducted independently in response to loans, whereas the other two regimes react only moderately to either house prices or output.

Table 6: Conditional welfare under optimized regimes

	Welfare values		
Regimes	Total	Patient HHs	Impatient HHs
Baseline policy,			
$m_\chi = 0.75, \gamma_R = 0.9, \gamma_\pi = 2, \gamma_y = 0.15$			
	$-3,436.73$	$-343,583.19$	$-26,427.84$
Policy response to GDP growth,			
$m_\chi = 0.75, \gamma_R = 0.9, \gamma_\pi = 2, \gamma_y = 0.15, \gamma_{my} = 0.5, \gamma_{ml} = 0, \gamma_{mp} = 0$			
Common macro-prudential policy	$-3,436.75$	$-343,582.81$	$-26,428.22$
	(-0.02)	(0.38)	(-0.38)
Independent macro-prudential policy	$-3,435.75$	$-343,581.94$	$-26,428.28$
	(-0.02)	(1.25)	(-0.44)
Policy response to loans,			
$m_\chi = 0.75, \gamma_R = 0.9, \gamma_\pi = 2, \gamma_y = 0.15, \gamma_{my} = 0, \gamma_{ml} = 0.1, \gamma_{mp} = 0$			
Common macro-prudential policy	$-3,435.79$	$-343,581.44$	$-26,428.98$
	(-0.07)	(1.75)	(-1.15)
Independent macro-prudential policy	$-3,435.79$	$-343,580.01$	$-26,429.06$
	(-0.06)	(3.18)	(-1.22)
Policy response to house prices,			
$m_\chi = 0.75, \gamma_R = 0.9, \gamma_\pi = 2, \gamma_y = 0.15, \gamma_{my} = 0, \gamma_{ml} = 0, \gamma_{mp} = 0.5$			
Common macro-prudential policy	$-3,435.76$	$-343,582.79$	$-26,428.34$
	(-0.03)	(0.41)	(-0.50)
Independent macro-prudential policy	$-3,435.76$	$-343,581.95$	$-26,428.43$
	(1.24)	(-0.59)	(-0.03)
Optimized monetary policy and macro-prudential policy,			
$m_\chi = 0.75, \gamma_R = 0.9, \gamma_\pi = 2, \gamma_y = 0.15, \gamma_{my} = 0.5, \gamma_{ml} = 0.1, \gamma_{mp} = 0.5$			
Common macro-prudential policy	$-3,435.85$	$-343,576.89$	$-26,430.30$
	(-0.13)	(6.30)	(-2.46)
Independent macro-prudential policy	$-3,435.85$	$-343,572.75$	$-26,430.60$
	(-0.13)	(10.44)	(-2.77)

Note: In parentheses, individual welfare gain/losses with respect to the baseline policy.

The analysis of the model economy suggests that macro-prudential policy results in a welfare loss for borrowers because of the transmission mechanism underpinning the shock process. That is, given changes in all the shocks in the model economy, macro-prudential policy increases the cyclicality of interest rate on loans. This in turn increases the volatility of borrowing, thereby decreasing borrowers' welfare. For instance, as shown in Figure 5, when a productivity shock hits the economy, it causes the level of housing investment and house prices to rise, while the number of loans decreases. Similar results are reported by Campbell and Hercowitz (2009) and Quint and Rabanal (2014). In addition, a comparison of the second moments from the data in Table 3 with those resulting from welfare analysis shows that macro-prudential policy results in a decrease in the volatility of output and loans. This implies that the implementation of a macro-prudential policy helps to deliver financial stability in the model economy. This finding is also consistent with the literature.

6 Conclusion

This paper investigates the welfare cost of macro-prudential policy using a two-country DSGE model with financial frictions. Using second order approximation, I show that macro-prudential policy results in a welfare trade-off between patient and impatient households. I find that macro-prudential policy tends to benefit patient households more than impatient households. By decreasing the volatility of loans uptake and output growth, macro-prudential policy could help to ensure financial stability in South Africa.

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Appendices

Appendix A: Full non-linear model

Patient households:

$$P_t c_{p,t}(\imath)+P_{\chi,t}\left(\chi_{p,t}(\imath)-(1-\delta_\chi)\chi_{p,t-1}(\imath)\right)+D_{p,t}(\imath)=\left\{W_{p,t}(\imath)\,n_{p,t}(\imath)+R_{k,t}k_p(\imath)+R_{t-1}D_{p,t-1}(\imath)+\Pi_{p,t}(\imath)\right\}. \tag{A.1}$$

$$\lambda_{c,t}^p=\frac{-\sigma_c}{1-\xi_c}\left(c_{p,t}(\imath)-\xi_c c_{p,t-1}\right)+\varepsilon_{u,c}, \tag{A.2}$$

$$\lambda_{c,t}^p=E_t u_{c,t+1}^p+R_{D,t}-E_t\pi_{t+1}, \tag{A.3}$$

$$\sigma_\chi\chi_{p,t}=u_{c,t}^p-P_{\chi,t}+\frac{\beta_p^t(1-\delta_\chi)}{1-\beta_p^t(1-\delta_\chi)}\left(E_t\pi_{\chi,t+1}-R_{D,t}\right)+\varepsilon_{u,c}\varepsilon_{\chi,c}A_\chi, \tag{A.4}$$

$$w_t=A_n\frac{{n_{p,t}}^{\sigma_n}}{c_{p,t}}. \tag{A.5}$$

Impatient households:

$$P_t c_{i,t}(\imath)+P_{\chi,t}\left(\chi_{i,t}(\imath)-(1-\delta_\chi)\chi_{i,t-1}(\imath)\right)+R_{L,t-1}L_{i,t-1}(\imath)\leq W_{i,t}(\imath)\,n_{i,t}(\imath)+L_{i,t}(\imath). \tag{A.6}$$

$$R_{L,t}L_{i,t}(\imath)\leq m_{\chi,t}E\left\{P_{\chi,t-1}\right\}(1-\delta_\chi)\chi_{i,t}(\imath). \tag{A.7}$$

$$\lambda^i_{c,t} = \frac{-\sigma_c}{1-\xi_c}\left(c_{i,t}\left(\imath\right) - \xi_c c_{i,t-1}\right) + \varepsilon_{u,c}, \tag{A.8}$$

$$\left[1 - \beta_i^t\left(1-\delta_\chi\right) + \left(\beta_i^t - \frac{\overline{\pi}}{\overline{R}_L}\right)\overline{m}_\chi\right]\left(\xi_\chi - \sigma_\chi \chi_{i,t}\right) = \lambda^i_{c,t} - P_{\chi,t} + m_\chi \beta_i^t E_t \lambda^I_{c,t+1} + \Lambda, \tag{A.9}$$

Housing goods producers:

$$\chi_t = \left(1-\delta\right)\chi_{t-1} + \varepsilon_{I\chi,t}\left(1 - S_\chi\left(\frac{I_{\chi,t}}{I_{\chi,t-1}}\right)\right)I_{\chi,t}. \tag{A.10}$$

Intermediate goods producers:

$$c_{H,t}\left(q\right) + \frac{1-\omega}{\omega}c^*_{H,t}\left(q\right) + I_{\chi,t}\left(q\right) = z_t k\left(q\right)^\alpha n_t\left(q\right)^{1-\alpha}. \tag{A.11}$$

Banks:

$$E_0\left\{\beta_p \frac{u_{p,t+1}}{P_{t+1}}\left[R_{L,t}\left(j\right)L_t\left(j\right)\right] - R_t D_t\left(j\right) - S_{t+1}\rho_t R^*_t \widetilde{D}^*_t\left(j\right)\right\}. \tag{A.12}$$

$$L_t\left(j\right) = D_t\left(j\right) + S_t \widetilde{D}^*_t\left(j\right). \tag{A.13}$$

$$\omega_I L_{I,t} = \left(\int_0^1 L_t\left(j\right)^{\frac{1}{\mu_L}}\,dj\right)^{\mu_L}. \tag{A.14}$$

Closing the model:

$$y_t \equiv c_{H,t} + c^*_{H,t}\frac{1-\omega}{\omega} + I_{\chi,t}. \tag{A.15}$$

$$\widetilde{D}^*_t = P_{F,t}c_{F,t} - \frac{1-\omega}{\omega}P^*_{H,t}c^*_{H,t} + \varrho_{t-1}R^*_{t-1}\widetilde{D}^*_{t-1}. \tag{A.16}$$

$$n_t = \omega_p n_{p,t} + \omega_i n_{i,t}. \tag{A.17}$$

$$\beta_p^t \chi_{p,t} + \beta_i^t \chi_{i,t} = \chi_{t-1}. \tag{A.18}$$

$$\int_0^1 c_{H,t}(q)\,dq + c^*_{H,t}(q)\,dq = y_t. \tag{A.19}$$

Monetary policy:

$$\frac{R^*_t}{R^*} = \left(\frac{R^*_{t-1}}{R^*}\right)^{\gamma^*_R} \left[\left(\frac{\widetilde{\pi}_t}{\widetilde{\pi}^*}\right)^{\gamma^*_\pi} \left(\frac{\widetilde{y}_t}{\widetilde{y}}\right)^{\gamma^*_y}\right]^{1-\gamma^*_R} e^{\varepsilon^*_{R,t}}. \tag{A.20}$$

Macro-prudential policy:

$$\frac{m_{\chi,t}}{m_\chi} = \left(\frac{l_t}{l}\right)^{\gamma_{ml}} \left(\frac{p_{\chi,t}}{p_\chi}\right)^{\gamma_{mp}} \left(\frac{y_t}{y}\right)^{\gamma_{my}}. \tag{A.21}$$

Appendix B: Data and sources

Data source: South Africa from South African Reserve Bank Quarterly Bulletin and U.S. from the St. Louis Federal Reserve Economic Data (FRED).

South Africa

RGDP: Gross domestic product at market prices (KBP6006Y), millions of rands, constant 2010 prices.

Residential investment: Gross fixed capital formation: residential buildings (KBP6110Y), millions of rands, constant 2010 prices.

Housing loans: Total mortgage loans outstanding (KBP1480M), millions of rands, constant 2010 prices.

House prices: ABSA Bank house price based on total purchase price of all houses (including all improvements) for which loan applications were approved by ABSA. Houses whose prices exceeded R3,500,000 in 2011 excluded from the calculations. Prices smoothed for all houses between 80m^2 and 400m^2, millions of rands, constant 2012 prices.

Household consumption: Final consumption expenditure by households (KBP6007Y), millions of rands, constant 2010 prices.

Foreign exchange rate: South African rand to one U.S. dollar (EXSFUS), annual, not seasonally adjusted.

Mortgage interest rate: Predominant rate on new mortgage loans (KBP2011J): banks –dwelling units.

Inflation: Implicit Price Deflator - Percentage of the ratio of Gross domestic product at market prices (KBP6006J), millions of rands, current prices to Gross domestic product at market prices (KBP6006Y), millions of rands, constant 2010 prices.

U.S.

RGDP: Real gross domestic product (GDPMC1), millions of chained 2009 dollars, constant annual, seasonally adjusted annual rate.

Residential investment: Households and nonprofit organizations; gross fixed investment residential equipment, software, and structures (includes farm houses), Flow (HNOGFRQ027S), Millions of Dollars, Annual,

Housing loans: Mortgage Debt Outstanding, All holders (MDOAH), Millions of Dollars, Annual, Not Seasonally Adjusted.

House prices: New single-family houses sold: U.S. dollars, not seasonally adjusted, average sales price.

Household consumption: Real personal consumption expenditures (PCECC96), billions of chained 2009 dollars, annual, seasonally adjusted annual rate.

Mortgage interest rate: 30-year conventional mortgage rate (MORTG), monthly, not seasonally adjusted.

Inflation: Gross Domestic Product: Implicit Price Deflator (GDPDEF), Index 2009=100, quarterly, seasonally adjusted.