Bank of Finland

BoF Economics Review

1 • 2021

Economic effects of a debt-to-income constraint in Finland – Evidence from Aino 3.0 model

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Abstract

We analyze the economic effects of a debt-to-income constraint for the Finnish economy. Our benchmark is a DSGE model which is designed to capture the most prominent features of the Finnish economy and is calibrated using Finnish macroeconomic data. The baseline model incorporates a loan-to-value type of constraint for new mortgage loans. We study the effects of replacing this with a neutral DTI constraint, neutral meaning that the level of the constraint is set so that it would not alter the mortgage loans-to-GDP ratio in the long run. We find that the replacement would have only small long run effects on the economy, and it would potentially reduce the volatility of several variables associated with the housing markets.

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The authors would like to thank Meri Obstbaum, Fabio Verona, Juha Kilponen, Markus Sihvonen, Paavo Miettinen, Ville Voutilainen and seminar participants in the Bank of Finland and FIN-FSA for valuable comments. We would also like to thank Petteri Juvonen for invaluable help with the Aino 3.0 model and for providing useful insights for the analysis.

1. Introduction

Financial stability considerations rose on a global agenda in the aftermath of the 2008 financial crisis and the following Euro area debt crisis. In the first stage, banks' countercyclical capital buffers were introduced. Soon after, the emphasis turned to household indebtedness and demand side macroprudential tools. Finland, among other countries, introduced measures to restrict the size of loans that banks can offer their customers by restricting their *loan-to-collateral* (LTC) ratios.[1] In addition, a working group of Ministry of Finance has recently proposed to cap the loans based on the customers' income, using *debt-to-income* (DTI) type of restrictions, to further curb the indebtedness of Finnish households[2].

Functioning capital markets and the banking sector's ability to allocate loans to households are essential for the functionality of the economy. Evaluation of the solvency of the households is core business for the banks. There are, however, some externalities that are not incorporated into banks' lending procedures. There is prominent evidence that the economic downturns are the more severe, the faster leverage growth preceded it.[3] Economic downturn forces households to adjust their consumption, and the tighter is their income to their debt service costs, the more they need to cut their consumption. This creates a potential case for regulating the mortgage lending from the macroprudential point of view. Our main goal in this paper is to provide evidence on costs and benefits of the two constraints. The costs might occur both from the increased volatility in the economy, or from slowed down economic activity. The benefits, vice versa, from reduced volatility or enhanced activity.

As a tool of analysis, we utilize the Aino 3.0 model recently developed at the Bank of Finland. We study the effects of a neutral DTI constraint, which means that the level of the constraint is calibrated such that it would not alter the *mortgage loans-to-GDP* ratio in the long run. We find evidence that the DTI constraint, compared to the LTV constraint, would reduce volatility in mortgage lending and house price inflation. The LTV constraint is pro-cyclical, meaning that it allows more lending when house prices increase. DTI would curb debt growth in this case if the house prices grow faster than the income level. We also find that the biggest differences between the two constraints, in the short run, occur when the turbulence is caused by a shock in the banking sector or affects directly interest rates.

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[1] A comprehensive list of macroprudential tools and which European countries have implemented them can be found in Review of Macroprudential Policy in Europe, ESRB (2019).
[2] See [Household indebtedness must be curbed with new measures (valtioneuvosto.fi)](valtioneuvosto.fi).
[3] Mian and Sufi (2010) provide evidence on this using heterogeneity in U.S. counties. Based on micro level data, a pattern has been documented in Andersen, Duus, and Jensen (2016), and in Chapter 6 in Bunn et al. (2016). Mian and Sufi (2018) summarizes existing literature on credit-driven household demand channel, and more evidence to back it up. Verner and Gyöngyösi (2020) studies a natural experiment and conclude that an exogenous shock to household debt caused economic activity to slow down. There is also a vast literature on households' debts predictive power on financial crises (e.g. Reinhart and Rogoff (2009), Tölö, Laakkonen, and Kalatie (2018), Lainá, Nyholm, and Sarlin (2015) (using a long Finnish data), which are a crucial factor for the severity of the crises.

Analysis of the costs and benefits of new kind of a macroprudential tool is tricky for several reasons. Globally, these instruments have been established at rather volatile times, in many occasions, right after the financial crises in 2008. Short time series data and small variation in levels of instruments make it difficult to identify the effects of the policy actions.[4] Second, there is a considerable amount of heterogeneity between countries. The experience in one country should not be straightforwardly taken as an approximation of the consequences in another country without properly addressing the countries' distinctive features. For these reasons, a structural macroeconomic model designed to capture the relevant properties of the Finnish economy lends itself well to the present analysis.

Recent years have seen an increase in the number of studies that analyze the effects of various macroprudential policy tools in the context of dynamic stochastic general equilibrium (DSGE) models. This paper is related to the previous studies that examine different borrower-based macroprudential policy tools acting in the housing market. In practice, often-employed tools include caps on loan-to-value (LTV) or loan-to-collateral (LTC) ratios, as well as debt limits or debt service limits that are tied to borrowers' income. While LTV-type regulations have been analyzed quite extensively in DSGE models[5], income-based tools have, until recently, received relatively less attention.

Grodecka (2020) analyses the interaction of LTV and debt-service-to-income (DSTI) constraints in a small-scale New Keynesian model. Her main finding is that stricter LTV policies may in fact fail to bring down the debt-to-GDP ratio if borrowers simultaneously face a binding DSTI constraint. Chen et al (2020) separately examine the costs of various macroprudential tools in a model similar to Grodecka's. They find that, while the differences in long-run output losses are quite modest across different policy tools, short-term effects are more heterogenous. Specifically, in an environment where monetary policy is constrained by a zero lower bound and the debt level of the economy is high, an LTV tightening can result in a larger short-term drop in consumption and output than a tightening in an income-based policy tool[6]: an LTV tightening induces a greater decline in house prices and triggers a more severe fall in aggregate demand as decreased collateral values restrict the ability of borrowers to obtain loans. However, when monetary policy is unconstrained and debt levels are low, the differences in short-term costs of different policies are modest.

[4] *Mokas and Giulliudori (2021) uses high frequency identification methods to extract the exogenous variability in LTV constraints in EU and use this to study the effects of the macroprudential shocks. Panel regression evidence on the economic effects of macroprudential policies can be found in Lim et al. (2011), Kuttner and Shim (2016), Akinici, and Olmstead-Rumsey (2018), and Cerutti (2017). A narrative approach for identify LTV shocks has been adopted in Richter and Shim (2018), and in the case of bank capital regulation, in Eickmeier (2017).*

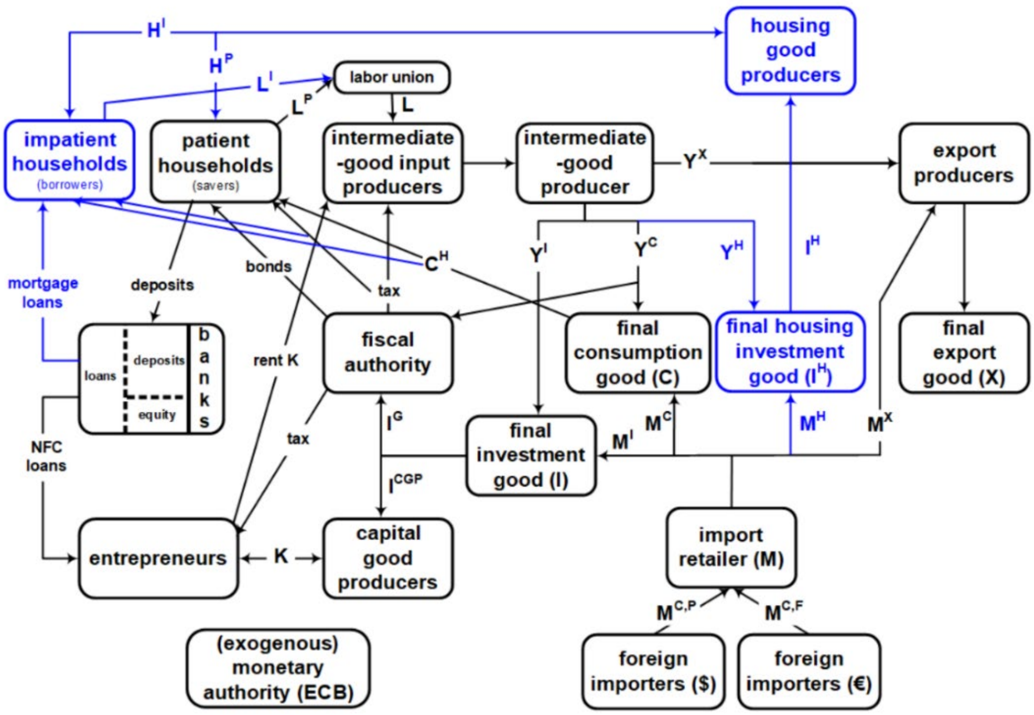
[5] *See, among others, Iacoviello (2005, 2015), Iacoviello and Neri (2010), Gerali et al (2010), and Justiniano et al (2015).*

[6] *Income-based tools that Chen et al (2020) consider are DSTI and loan-to-income (LTI) limits. The former restricts the borrower households' debt service costs on new loans (consisting of interest and amortization) to a multiple of their total income. The latter simply states that the household's new loan cannot exceed a certain multiple of its total income.*

Millard et al (2021) analyze the properties of various macroprudential tools in a DSGE model with financial frictions. They find that a constraint on debt-service-ratio (DSR) does a better job in containing the volatilities of the key macroeconomic variables than an LTV constraint, since the former disconnects the housing market from the real economy, preventing a lending boom driven by increasing collateral values. In addition, DSR limits are welfare-improving compared to other macroprudential tools the authors analyze.

The present paper is closely related to above mentioned studies in that we compare the macroeconomic effects of LTV and income-based macroprudential policies in the context of a DSGE model, complementing the relatively scarce literature on the analysis of latter type tools in such models. Specifically, we focus on a model that is designed to match certain properties of the Finnish economy. The model thus provides us with a laboratory suitable for the analysis of the macroeconomic effects of the policy reform that is currently discussed in Finland.

Figure 1. Structure of the Aino 3.0 model



Source: Silvo and Verona (2020).

The next Section describes the Aino 3.0 model developed by Silvo and Verona (2020) and introduces the two constraints of interest, the LTV and the DTI constraints. In Section 3 we provide a quantitative analysis of the model. We study long run steady state effects of changing the constraint from an LTV to a neutral level DTI. We also study the long run variability of the variables under both regimes. Short run dynamics and the effects of certain shocks are inspected by drawing impulse responses of the variables under each policy regime. We also provide some sensitivity analysis in order to ensure the robustness of our results. In Section 4 we discuss some of the caveats of our modelling approach, and Section 5 concludes. In Appendix we provide further sensitivity and robustness considerations, as well as pictures with impulse responses of larger set of variables than is reported in the main text. We also report some selected moments computed from the baseline model and compare them with the moments computed from the Finnish data.

2. The Aino 3.0 model

2.1. General structure

The Aino 3.0 model is a medium-scale DSGE model developed by Silvo and Verona (2020). It is the latest edition in the line of DSGE models developed for the Finnish economy at the Bank of Finland, following the original life cycle Aino model (Kilponen, Kinnunen, and Ripatti, 2006) and the small open economy DSGE model Aino 2.0 (Kilponen, Orjasniemi, Ripatti, and Verona, 2016). Figure 1 illustrates the structure of the model and its main differences to its latest predecessor. The Aino 3.0 model features some degree of heterogeneity in the household sector. Another novel feature compared to the earlier model versions is that it also includes housing markets and multiperiod mortgage loans, modelled following the novel framework proposed by Kydland, Rupert, and Sustek (2016).

The heterogeneity is implemented via two types of consumers. A fraction of consumers in the economy are patient, while the remaining fraction are impatient[7]. The patient agents are considered wealthy savers. They do not need to borrow money from the bank, but they can use their savings for consumption and housing purchases. On the other hand, the impatient consumers are dependent on bank loans and are constrained by the *loan-to-value* (LTV) constraint, when it comes to borrowing for housing consumption.

Housing investment is an important driver of the business cycle in Finland. As pointed out in Silvo and Verona (2020), housing investment is also pro-cyclical and tends to increase relative to GDP in booms and decrease in busts. The housing construction sector also serves as a link between housing prices and real economy. Whenever the housing prices are expected to rise, the investment increases and adds to economic activity. This is a part of the economy that is included to the Aino 3.0 model, and it plays a crucial role in our analysis. Effects of the borrowing constraints are particularly visible in these sectors.

[7] Patient and impatient households differ in how they discount their future utility: impatient households place relatively more emphasis on current utility than patient households, which drives them to borrow in equilibrium. This kind of distinction between households introduces saver-borrower behavior into the model, in accordance with Iacoviello (2005) and several other papers.

2.2. Borrowing constraints

The Aino 3.0 model incorporates a *loan-to-value* (LTV) type of constraint for households' new borrowing. The value of the collateral, i.e. the value of households' new housing, determines the maximum level of new debt the household can borrow each period. In model calibration, the fraction is set to 90%, accordingly to the current Finnish macroprudential policy regulation.

In this paper we consider an alternative version of the Aino 3.0 model where the LTV constraint is replaced with a *debt-to-income* (DTI) constraint for household debt. This constraint sets a roof for households' total debt as a multiple of the household's disposable income. In both versions of the model, the constraint is assumed to be always binding for the impatient households, and they demand mortgages up to the maximum amount allowed by the policy constraint. Even though the models are otherwise identical, changing the constraint has important consequences for the model behavior, as our analysis will show.

In Aino 3.0, mortgages are modelled as in Kydland et al (2016). Each period, a typical borrower household decides on the flow of new mortgages, $BL_t^{H,new}$. The entire stock of mortgages then evolves according to the following law of motion:

$$BL_{t+1}^H = BL_t^{H,new} + (1 - \gamma_t^H) BL_t^H,$$

where BL_{t+1}^H denotes the stock of mortgages in the beginning of period $t+1$. Borrower households amortize the outstanding mortgages at a time-varying rate γ_t^H, which is determined endogenously according to:

$$\gamma_{t+1}^H = \left(1 - \frac{BL_t^{H,new}}{BL_{t+1}^H}\right) (\gamma_t^H)^{\alpha_M} + \frac{BL_t^{H,new}}{BL_{t+1}^H} \kappa.$$

Here, α_M and κ are parameters that govern the time profile of a mortgage loan. In accordance with Silvo and Verona (2020), the values for α_M and κ are chosen so as to match the average initial mortgage maturity of approximately 20 years.[8]

Analytically, the LTV constraint that restricts a typical borrower household in the Aino 3.0 model can be expressed as

$$BL_t^{H,new} = \theta_t^{LTV} P_t^H [H_{t+1}^I - (1 - \delta_t^H) H_t^I],$$

where P_t^H is the house price, and $H_{t+1}^I - (1 - \delta_t^H) H_t^I$ is the new housing purchased by the household, where δ_t^H is the rate of depreciation of the housing stock. θ_t^{LTV} is the macroprudential policy parameter that determines the amount of lending that the household can obtain as a fraction of the value of new housing being purchased.[9]

[8] As shown in Silvo and Verona (2020), the maturity of mortgages is an important driver of model dynamics when an LTV constraint is in place. In our subsequent robustness analysis, we explore the significance of mortgage maturity in the context of a DTI constraint, too.

[9] Note that several earlier papers (e.g. Iacoviello 2005) have assumed that the LTV limit applies to the stock of mortgages, and that eligible collateral consists of the value of the entire housing stock owned by the household, i.e.

In the DTI version of the model, a typical borrower household faces a constraint that links the amount of lending to its disposable income. The constraint can be written as

$$BL_{t+1}^{H} = \theta_t^{DTI} Income_t^{I},$$

where BL_{t+1}^{H} is the total mortgage debt of the borrower household, and $Income_t^{I}$ denotes its disposable income. The disposable income consists of the labor income received from working, net of the lump-sum taxes imposed by the government.[10] θ_t^{DTI} is again the macroprudential policy parameter. Unlike the baseline LTV constraint, the DTI limit is subject to the entire debt stock of the household, following the policy proposal of the Ministry of Finance.

The two previously described constraints give rise to different mechanisms in the model. The LTV version exhibits a "financial accelerator" mechanism: exogenous shocks that positively affect house prices increase the value of collateral, effectively relaxing the borrowing constraint and allowing for more mortgage lending. Increased mortgage borrowing capacity boosts housing demand, leading to a further increase in house prices, even greater collateral values, and so on. This kind of amplifying mechanism is absent from the DTI version, as the constraint shuts off the direct channel between house prices and mortgage borrowing. Instead, the DTI constraint works through the labor supply channel: households can accommodate exogenous changes in the borrowing limit by altering their wage rate and labor supply[11].

3. Quantitative analysis

This section presents a quantitative comparison of different macroprudential constraints. First, we compare the long-run effects of the two constraints. Second, we consider the short-run dynamic behavior of the model in response to various economic shocks, assuming that either an LTV or a DTI constraint is in place.

3.1. Long run equilibrium analysis

The first three columns of Table 1 show the long-run equilibrium[12] values of selected macroeconomic variables under different parameterizations of the DTI parameter. We compare the

the constraint is written as $BL_{t+1}^{H} = \theta_t^{LTV} P_t^{H} H_{t+1}^{I}$. In these studies, housing wealth serves as collateral for general-purpose loans with one-period maturity. A flow-type LTV constraint, like the one assumed in this paper, more closely resembles an actual mortgage contract in that it implies that a new mortgage loan is taken to finance the purchase of new housing. For a discussion on the difference between the two forms of the constraint, see Kydland et al (2016).

[10] *In the model, the lump-sum taxes can be negative, in which case the government endows a lump-sum transfer to the household.*

[11] *In Aino 3.0, labor markets are assumed to be imperfectly competitive. Households are monopolistic suppliers of differentiated labor services, and instead of taking the wage as given, each household sets the wage rate for its labor service and commits to supply any number of hours demanded at that wage. This assumption is common in the literature and is made in order to facilitate the incorporation of nominal wage stickiness into the model.*

[12] *Throughout the paper, by long run equilibrium we mean the non-stochastic steady state of the model, which is defined as the equilibrium along which the stationarized model variables are constant. For details, see Kilponen et al (2016) and Silvo and Verona (2020).*

values to those obtained under the current LTV regulation, which yields a mortgage-loans-to-GDP ratio of 147 % in the model, a figure close to the average value calculated from the Finnish data over the period of 1996Q1 – 2019Q4.

We consider three different scenarios regarding the tightness of the DTI limit. In the "neutral DTI" scenario, the parameter θ^{DTI} is set to value that yields the same steady-state mortgage-to-GDP ratio as the baseline LTV model (that is, 147 % of quarterly GDP). In the "tight DTI" scenario, the policy parameter θ^{DTI} is set so that the steady-state mortgage-to-GDP ratio is 100 %. Conversely, in the "lax DTI" scenario the parameter is set to yield a steady-state ratio of mortgages-to-GDP of 200 %. For the first three columns of the table, the implied steady state mortgage-to-GDP ratios in each scenario are reported in the first row. Lower rows report the relative steady state values under DTI constraints with varying tightness. The values are relative to those obtained under a baseline LTV regime, i.e. with $\theta^{LTV} = 0.90$. Therefore, a number above 100 indicates that the steady state of a certain variable is higher under a DTI regime than under the baseline LTV. Conversely, a number below 100 indicates that the steady state is lower under a DTI relative to the baseline LTV.

Table 1. Long-run effects of the DTI constraint

		Tight DTI	Neutral DTI	Lax DTI	Standard deviations under neutral DTI, relative to current LTV regime ($\theta^{LTV} = 0.90$) (%)	
	Implied steady state mortgage-to-GDP ratio (%)	100	147	200	Mortgage-to-GDP ratio	42
Steady state values, relative to current LTV regime ($\theta^{LTV} = 0.90$) (%)	Mortgage loans	68	101	140	Mortgage loans	51
	Private consumption	100	101	103	Private consumption	102
	Private output	100	103	105	Private output	94
	House price inflation	100	100	100	House price inflation	89
	Labor income	99	101	103	Labor income	97
	Real wage	100	100	100	Real wage	99
	Hours worked	100	101	103	Hours worked	92

For the first three columns of the table, the implied steady state mortgage-to-GDP ratios for DTI constraints of different levels are reported in the first row. Lower rows report the steady state values under DTI constraints relative to those obtained under a baseline LTV regime, i.e. with $\theta^{LTV} = 0.90$. A value above 100 indicates that a variable attains a higher vale under the DTI constraint than under the baseline LTV: for example, a value of 105 would indicate that the value of a variable is 5 % higher under the DTI than under the LTV with $\theta^{LTV} = 0.90$. The last column of the table reports the long-run standard deviations of variables under a neutral DTI regulation, relative to those obtained under the baseline LTV.

The middle column shows the relative long-run values under a DTI regulation when the parameter is set to a value that would yield the same long-run mortgages-to-GDP ratio as the current LTV regulation, i.e. a neutral DTI regime. All in all, the long-run effects of switching from an LTV to a DTI limit appear quite modest. A neutral DTI regime leads to a somewhat higher output in the long-run relative to an LTV regime (the “neutral DTI” column). Switching from a neutral DTI regime to a tighter DTI regulation (moving from the “neutral DTI” to the “tight DTI” column) would decrease the output somewhat in the long term. Similarly, hours worked would decrease somewhat. A possible explanation is that when the DTI regulation is tightened, the incentive of working is lower for the constrained households, as one extra hour of work can earn less additional borrowing than before. In the long run, lower labor input leads to lower production. Reverse logic would apply when the DTI constraint is loosened (moving from the “neutral DTI” to the “lax DTI”column).

The final column of the table shows the long-run standard deviations of variables under a neutral DTI regulation when the economy is buffeted by various shocks. Again, we report values relative to those obtained under current LTV regulation with $\theta^{LTV} = 0.90$. The volatility of mortgage loans and mortgages-to-GDP ratio decreases clearly when the economy switches from an LTV regulation to a DTI policy. Intuitively, under DTI, the borrowing capacity of households is unresponsive to house price developments, and changes in house prices caused by exogenous shocks do not trigger a similar amplifying mechanism as in the LTV case, as described above. Consequently, the volatility of mortgages is lower. The lack of amplification also leads to less volatile inflation of nominal house prices.

3.2. Short term dynamics

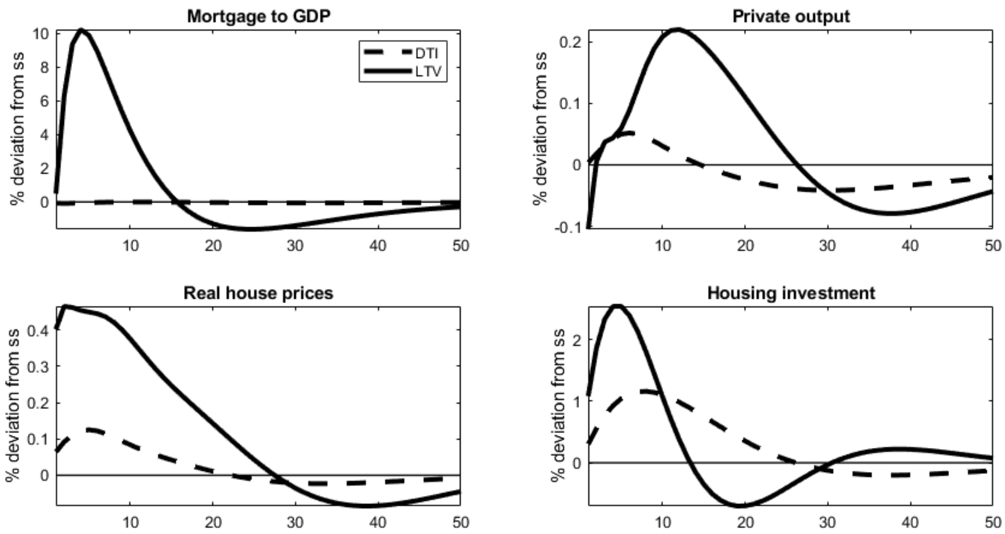
In this section we provide insight on the dynamics of the different constraints. We study the dynamics graphically by plotting the responses of selected variables to different shocks of the model. We provide the impulse responses of selected variables here in the main text, but report a larger set of variables and their impulse responses in the Appendix.

Shocks to banking sector

Figure 2 below and Figure 13 in the Appendix illustrate the dynamics in response to a shock to the mark-up on housing loans. The shock is such that it tightens the competition in the banking sector, leading to a decrease in the interest rate on mortgage loans.

Changes in the mortgage interest rates affects the demand of housing. All else equal, a decrease in the mortgage rate would make borrowing more attractive, leading to a higher demand for housing and higher house prices. With an LTV constraint in place, an increase in house prices initiates the financial accelerator mechanism: as the constraint is relaxed, mortgage borrowing increases and house prices increase even more. The DTI constraint is not affected by the house price changes, so the impatient households can get mortgage against their income as much as before the interest rate decrease. Constraint cuts effectively the chain between the real economy and banking sector shock. Because house prices change only little with a DTI constraint in place, housing investment does not react as much and effects on real economy are small compared to the LTV case.

Figure 2. Impulse responses of a shock to housing loan mark-up under LTV and DTI constraints

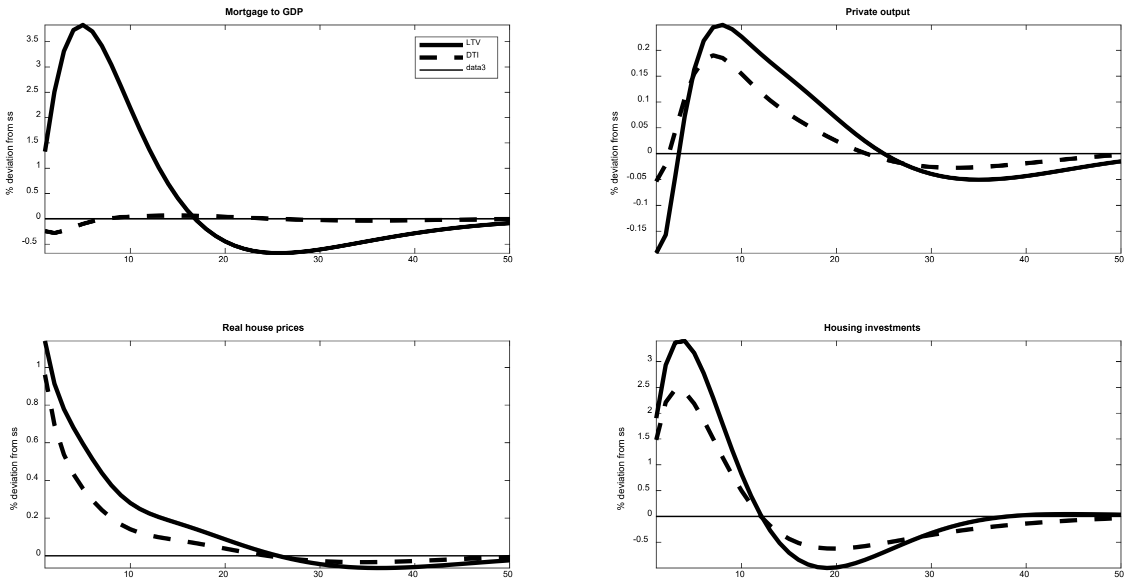


Numbers on the horizontal axes denote quarters.

Shocks to housing consumption preferences

Figure 3 in the main text and Figure 14 in the Appendix depict the impulse responses to a positive shock to housing consumption preferences. The shock increases the demand for housing. The initial effect of the increased demand would be a rise in house prices. Although the dynamics differ, the effects on the real economy are rather similar regardless of the constraint in place. Under the LTV constraint, impatient households' increased demand pushes house prices up and relaxes the constraint as the collateral value of the houses increase. The amount of new mortgage increase and non-housing consumption declines. As the house prices increase, despite the positive preference shock, patient households consume less housing. Then again, under the DTI constraint, it is the patient households that drive the house prices up as their demand increase. Impatient households would be willing to consume more, but as their income does not increase, the constraint prevents them to acquire more housing loan. Real effects of the preference shock are very much the same across different constraints.

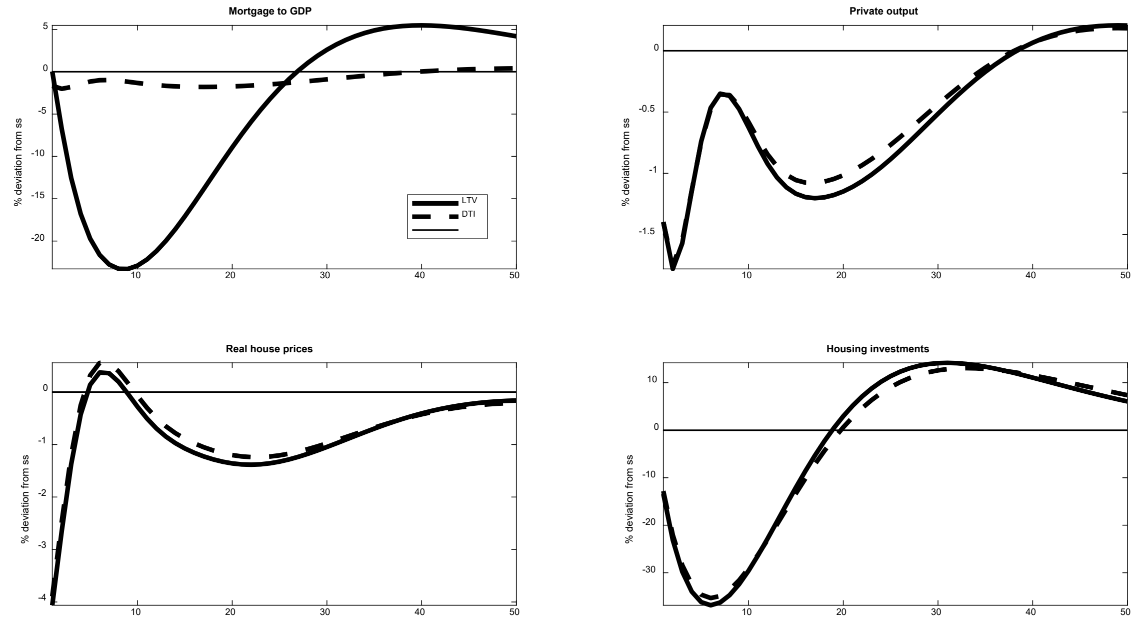
Figure 3. Impulse responses of a shock to housing consumption preferences under LTV and DTI constraints



Euro area interest rate shock

The euro area interest rate shock propagates into the real economy by increasing interest rates of mortgages. Consequently, the demand for mortgages decreases, and so does the impatient households' demand for housing. The relative price of housing decreases. Under the LTV constraint, the decline in house prices amplifies the shock's effect on mortgages as the borrowing constraint tightens. Under the DTI constraint, however, the households acquire mortgages as much as before the shock. Volatility in the housing markets is again much larger under the LTV regime because the initial effect of the reduced housing demand is amplified by the tightening of the constraint, and further reduced demand. The house prices fluctuate about the same amount in both cases. The unconstrained households benefit from the reduced house prices and increase their demand the more prices go down. Dynamics are illustrated in Figure 4 and Figure 16 in the Appendix.

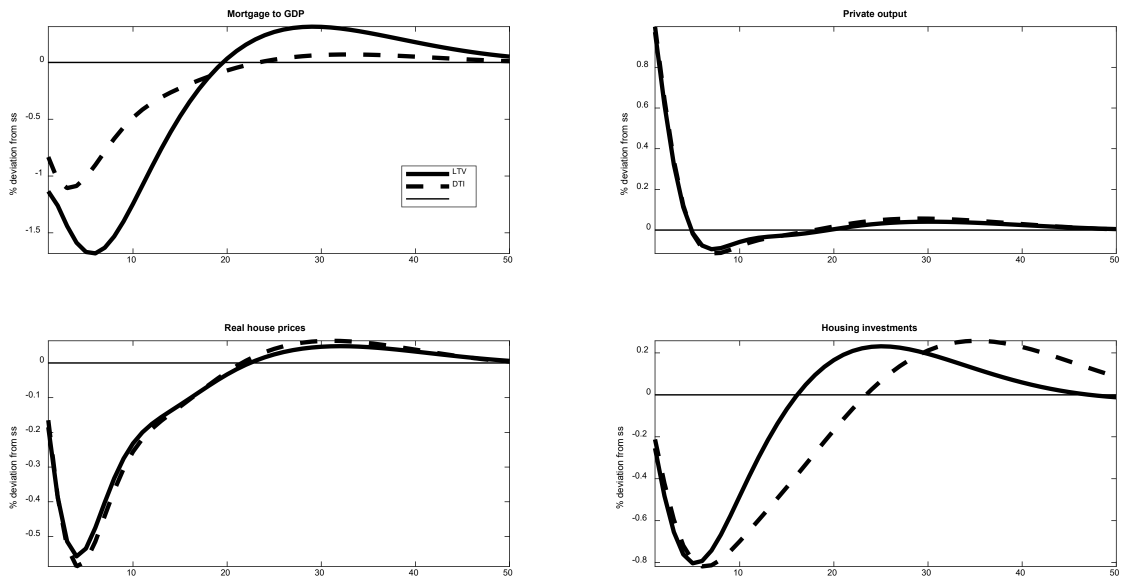
Figure 4. Impulse responses of a Euro area interest rate shock under LTV and DTI constraints



Macroeconomic shocks

The transmission of macroeconomic shocks to the real economy is not as dependent on the type of the constraint as the banking sector shocks. We illustrate this in Figure 5 in the main text and Figure 15 in the Appendix, where we have plotted impulse responses to a shock that increases the share the government spends on consumption goods. Especially, the reactions of output, consumption, and labor income are very similar. A shock to government consumption share boosts output. The shock's impact on house prices is identical as well, under both constraints. Whenever any shock changes the labor income, it alters the DTI constraint. Constrained households adjust their mortgages accordingly. This, however, is the case also under the LTV constraint. Increased income is distributed to housing and non-housing consumption so that the marginal utilities reflect the relative prices. The constraint is an important factor for the propagation of shocks when the shocks affect the relative prices, and not the income. Adjustment of demand and prices happens through different mechanisms depending on the constraint.

Figure 5. Impulse responses of a shock to government consumption share under LTV and DTI constraints



An anticipated macroprudential shock

We study the effects of an anticipated macroprudential tightening by imposing shocks to the DTI or the LTV constraint in a way that they would have the same long run impact on the mortgage loan to GDP ratio. Mimicking a likely way of implementing a policy reform in practice, we assume that a permanent tightening in the macroprudential policy is first announced and realizes four periods later. After this, there are no further changes to the policy, and households acknowledge this. Dynamics of a four quarters ahead anticipated shock are illustrated in Figure 6 and Figure 17 in the Appendix for both policy regimes.

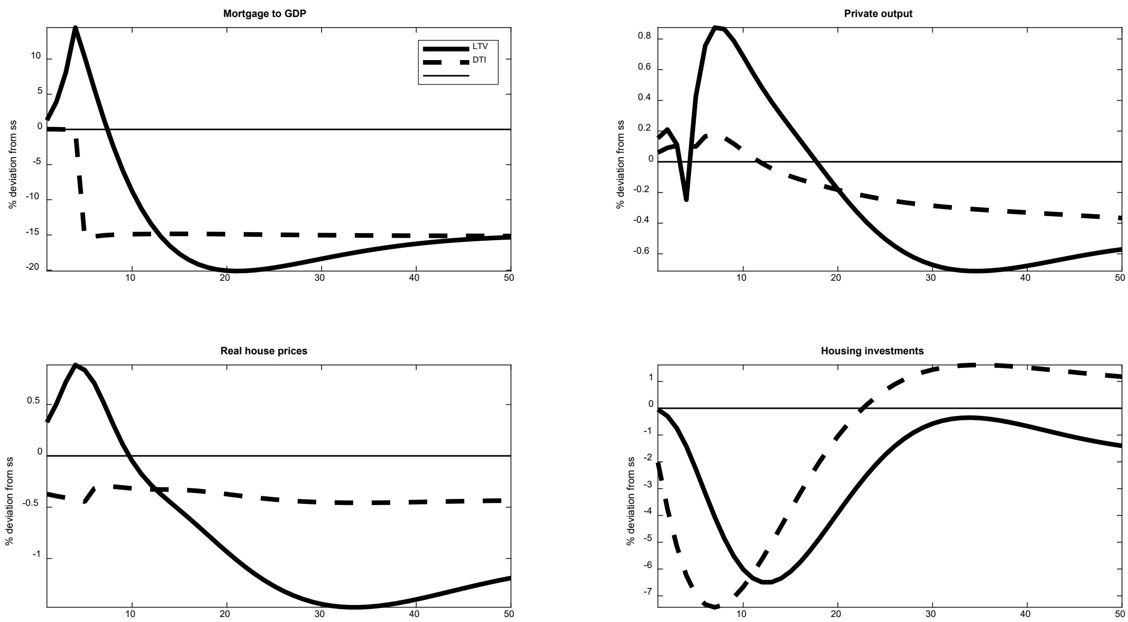
The anticipation effect is an essential part of the propagation of the shock under the LTV constraint. In this case, constrained households anticipate the future tightening of the constraint and acquire more mortgage loan before the shock hits the economy. House prices increase initially and relaxes the LTV constraint further, creating a cycle of more new mortgage loans and more demand for housing good. Patient households decrease their housing consumption initially and wait for the tightening to take place and the housing prices coming back down again.

Under the DTI constraint, the anticipation effect is almost completely dampened. Since the anticipation of the forthcoming macroprudential shock does not have any effects on labor income, the constrained households can do very little in order to react to the shock beforehand. When the shock occurs, the size of new mortgages declines instantly, reducing the demand for housing good. Because there is no anticipation effect, the swings in other macro variables remain smaller than in the LTV case.

From the policy maker perspective, it is important to take the anticipation effect into account. The longer the households are given time to react under the LTV constraint, the bigger are the real effects of the macroprudential shock. Then again, if the DTI constraint is in place, the real effects of the shock remain very much the same, no matter how far ahead the policy change has been announced. Anticipation effects with different horizons have been illustrated in Figure 11 and Figure 12 in the Appendix.

Economic fluctuations are larger under the LTV regime, especially if there is time for anticipation before the policy action is conducted. There is no big difference in housing investment, but house prices deviate more in the LTV case from their steady state. It is also notable that there is an initial increase in the housing prices after the policy announcements if the LTV constraint is in place. This might be an unwanted effect since the stricter policy is usually implemented exactly in order to harness the housing prices in boom.

Figure 6. Impulse responses of a 1-year anticipated macroprudential policy shock under LTV and DTI constraints



3.3. Sensitivity analysis

The above formulation of the DTI constraint assumes that the household's disposable income restricts the whole stock of mortgage loans, whereas the LTV constraint only applies to the flow of new mortgages. While this formulation of the DTI follows the policy proposal of the Ministry of Finance, it implies that in the model, the economy's entire debt stock immediately adjusts in response to changes in the DTI limit. With the DTI constraint formulated in terms of total mortgage stock, the multi-period nature of mortgage loans becomes obsolete because all borrower households refinance their entire debt stock each period in response to changes in the borrowing limit. Under the LTV regulation, the adjustment of the debt stock is sluggish because the borrowers adjust their new mortgage loans in response to changes in the borrowing limit[13]. This raises the concern that the differences in results between the two constraints might be due to the way they are formulated.

In this section we explore the sensitivity of our results to the formulation of the DTI constraint. We replace the standard DTI constraint with the following:

$$BL_t^{H,new} = \theta_t^{DTI} Income_t^I$$

so that the limit applies to the flow of new mortgage loans $BL_t^{H,new}$, as in the case of the LTV regulation. Table 2 presents the results from a long-run equilibrium comparison between LTV and DTI constraints when also the latter is formulated in terms of new loans. Again, the numbers in the table are relative to those that would be obtained under the current LTV regime with $\theta^{LTV} = 0.90$. As with our baseline results, switching from an LTV regulation to a neutral DTI would have very little effect on the steady state values of variables. Switching from a neutral DTI to a tighter (looser) DTI regulation would again result in a lower (higher) output in the long run, but the differences seem almost negligible. The tightness of the constraint mainly affects the long-run level of mortgage debt in the economy. In this respect, the results seem robust under the alternative specification of the DTI constraint.

Table 2. Long-run analysis when DTI constraint restricts new loans

		Tight DTI	Neutral DTI	Lax DTI	Standard deviations under neutral DTI, relative to current LTV regime ($\theta^{LTV} = 0.90$) (%)	
	Implied steady state mortgage-to-GDP ratio (%)	100	147	200	Mortgage-to-GDP ratio	70
Steady state values, relative to current LTV regime ($\theta^{LTV} = 0.90$) (%)	Mortgage loans	67	100	138	Mortgage loans	65
	Private consumption	99	100	101	Private consumption	94
	Private output	100	102	103	Private output	102
	House price inflation	100	100	100	House price inflation	80
	Labor income	99	100	101	Labor income	97
	Real wage	100	100	100	Real wage	99
	Hours worked	99	100	101	Hours worked	92

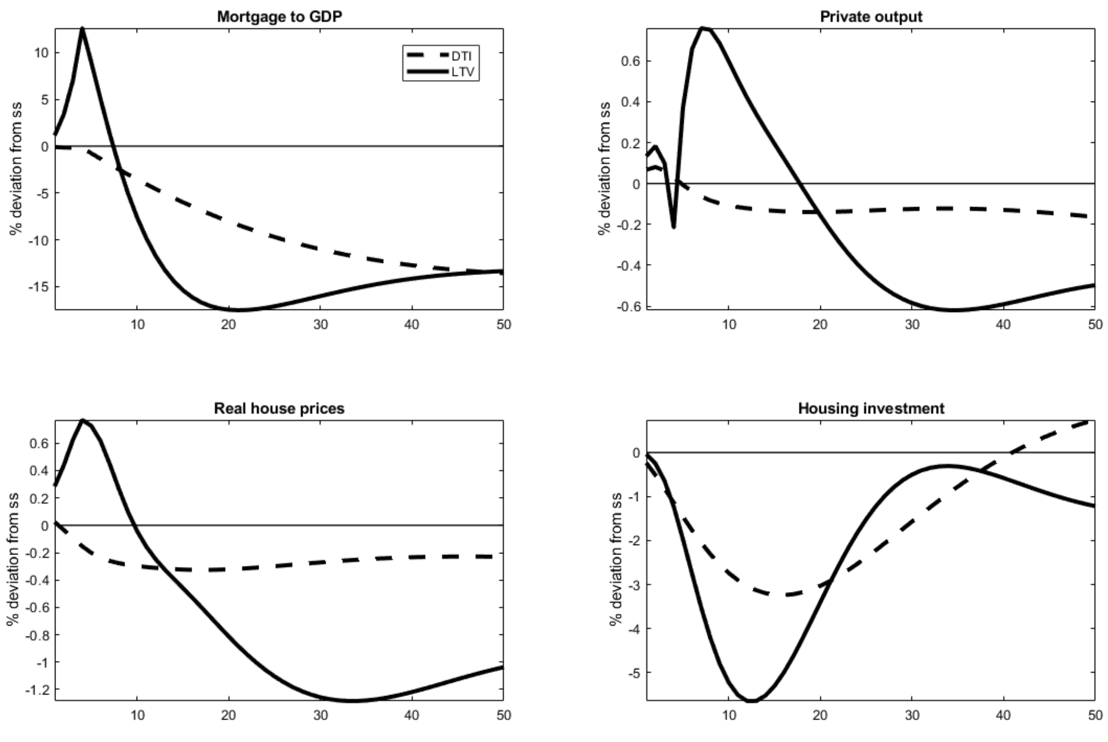
See Table 1 for further notes.

[13] *In the earlier literature analyzing the effects of LTV constraints, it has been fairly common to assume that mortgages are one-period loans. To capture the idea that in practice only a fraction of borrowers experience a change in their borrowing limit each period, some of these papers have assumed that the constraint depends on the lagged debt stock in addition to the collateral value of housing (see, for example, Iacoviello 2015, Iacoviello and Guerrieri 2017, and Ferrero et al 2018).*

However, whether the DTI constraint is formulated in terms of new loans or the entire loan stock does seem to have some effect on the volatilities of variables. In particular, the standard deviations of mortgage loans and mortgage-to-GDP ratio are higher when the constraint restricts new loans instead of the entire loan stock. Still, the volatilities are lower relative to the LTV regime: the relative standard deviations of mortgage-to-GDP ratio and mortgage loans are 70 % and 65 %, respectively. It thus seems that the result about the smaller volatility of mortgage loans under the DTI regulation is not driven simply by the different nature of the two constraints. All in all, long-run analysis appears quite robust to the formulation of the constraint.

We also conduct a sensitivity analysis on how the short-term dynamics are affected when the DTI constraint is changed to restrict new lending. Figure 7 plots the impulse responses to an anticipated macroprudential policy tightening, in a similar manner as presented in the results of the previous section. Again, shock sizes are scaled in a way that yields quantitatively similar response of the mortgage-to-GDP ratio under both constraints in the long run. As before, the announcement horizon is assumed to be 4 quarters, i.e. one year.

Figure 7. Impulse responses to an anticipated macroeconomic tightening when DTI constraint restricts new lending

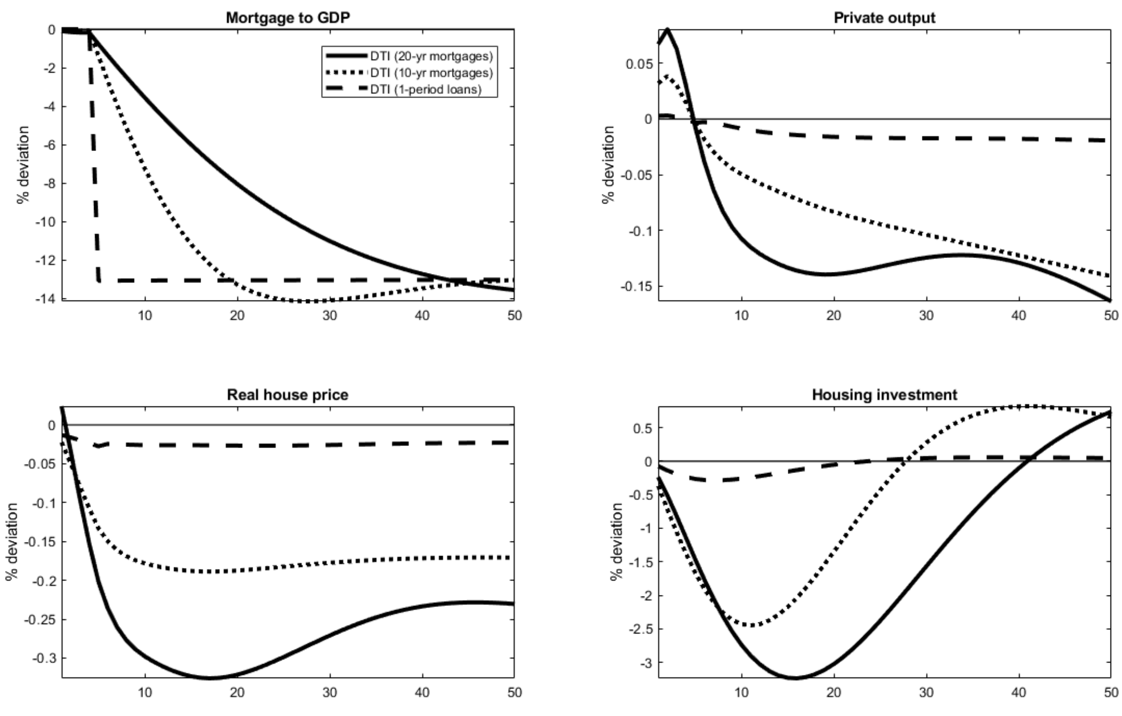


Looking at Figure 7, the most striking difference compared to the baseline results shown in the previous sections is the way the mortgage-to-GDP ratio behaves. When DTI limit restricts new lending, mortgages adjust sluggishly to the new equilibrium value once the tighter regulation comes into force, contrary to the standard case where the adjustment of mortgages is abrupt (see Figure 6). In terms of other plotted variables, the dynamics do not change qualitatively relative to the standard case. Again, the responses of variables seem more contained under a DTI than an LTV regime. Furthermore, there is no anticipation effect when DTI is in place, confirming the finding of the previous section. As changes in house prices do not affect the ability of the constrained household to obtain mortgages, there is no boom in mortgage borrowing following the policy announcement. This mechanism is unaltered whether the constraint is formulated in terms of the entire mortgage stock or the flow of new mortgage lending.

When the DTI constraint is formulated in terms of new loans, the maturity of the loans matters for model dynamics. We illustrate this in Figure 8, where the responses to an anticipated macroprudential tightening are plotted under alternative assumptions about the maturity of mortgages. The solid line represents the baseline case where the maturity is assumed to be 20 years. The dotted line shows the responses under 10-year mortgages, and finally, the dashed line depicts the responses under the assumption that mortgages are one-period loans.

The figure shows that mortgage maturity does indeed have implications on the dynamic behavior of variables. The longer the maturity, the stronger the responses to an announced macroprudential policy tightening are. In particular, the effects of policy changes are rather minor, in relative terms, when mortgages are assumed to be one-period loans. This confirms the finding of Silvo and Verona (2020) who analyzed the effects of different maturities in the context of an LTV constraint.

Figure 8. Effects of alternative mortgage maturities on dynamics when DTI constraint restricts new lending



4. Discussion

The purpose of this note is to provide evidence on differences of two constraints on mortgage loans in the context of a medium-scale dynamic general equilibrium model. The model is calibrated to Finnish economy and it is constructed to capture the essential features of a small open Euro area economy. There are some noteworthy aspects, however, that the model does not capture.

For example, in the proposal of working group of Ministry of Finance's on new macroprudential tools for curbing the households' debt growth, it was suggested to implement the DTI constraint in addition the LTC constraint already in place in Finland. In our analysis, we are not able to consider the effects of the different constraints effective at the same time. Steps towards this direction have been taken for example in Millard et al. (2021) and Grodecka (2020).

Related to this, another caveat in our analysis is that the model assumes that impatient households always face a binding borrowing constraint, while in reality households are likely to face a binding constraint only occasionally. In this respect, our result might overestimate the effects of policy changes because borrower households are always forced to adjust their behavior in response. However, as the constraint is assumed to be binding under both LTV as well as DTI, this is unlikely to distort the comparison between the two policy regimes. In future work, the model could be extended to allow for occasionally binding constraints although implementing them in large models like the one used here can be challenging. With this in mind, one possibility would be to simplify the model in some dimensions, while focusing on a more accurate modelling of the macroprudential constraints.

We are mainly concerned about the macroeconomic effects of the different constraints, and do not consider explicitly their effects on household welfare. It is thus worth emphasizing that the results presented here should not be interpreted as a welfare comparison of different macroprudential tools. Welfare analysis would require an objective based on which different policies are evaluated. Commonly, the literature has employed an approach where a micro-founded loss function is derived as a second-order approximation to households' utility function (see Benigno and Woodford, 2003). The Aino 3.0 model is solved using a first order linear approximation, and it does not feature a utility-based welfare criterion. In subsequent work, a more careful welfare analysis could be undertaken by extending the model to include a micro-founded welfare criterion, for example. Some other recent studies, such as Millard et al (2021), Ferrero et al (2018), and Rubio and Yao (2019), have analyzed the welfare properties of macroprudential policies, although the focus in this earlier literature has mostly been on the LTV-type regulations. A welfare comparison of LTV and DTI policies in the context of the Aino 3.0 model could therefore provide a fruitful avenue for future research.

Another limitation of the model is related to labor markets. The model abstracts from unemployment. Any arguments that rely on the fact that the labor income is rather stable hold only at the aggregate level. In real life, households face a risk of unemployment, and it alters the predictions about the future income. It would also create a need for modeling the safety net of the Finnish society, in order to capture all the essential effects that unemployment imposes to the economy.

Moreover, in reality, profit motives would likely drive banks to regulate their lending based on the income of the borrower or the value of collateral, even in the absence of any regulatory legislation. This would give rise to natural borrowing constraints, as the banks would find it optimal to regulate their lending to some extent. The model that we have used in the preceding policy exercises does not feature a possibility of a household defaulting on its mortgage loan, and hence such borrowing constraints do not arise endogenously. While beyond the scope of this paper, it would be worthwhile to study the macroprudential regulations in a more realistic setting where the banks engage in voluntary regulation. Related to the previous point about welfare, for example, it would be interesting to explore whether an equilibrium with governmental regulation would lead to a welfare improvement relative to the *laissez-faire* equilibrium, and whether any of the two macroprudential constraints considered here would in that sense be superior relative to one another.

There are certainly other factors as well that would be very much of the interest to any policymaker who has to design policy instruments. For example, we have aggregated over the lifecycle aspects of consumers. One interpretation of the households in this model is that it represents a family of individuals of different ages. On the other hand, the division of the households to patient and impatient can capture some of the lifecycle aspects of the real world because the constraints are clearly more binding when an individual has not yet had to time to save for their housing purchases. Another thing that our analysis lacks is the geographical aspect. Constraints on new loan may treat households differently depending on the housing price level of their living area. Moreover, the model does not feature a possibility of renting a house, which is an important type of living in Finland, and therefore ignores the potential effects of policy reforms on the rental markets. These issues should be thought about using other appropriate tools before implementing a policy reform in practice.

5. Conclusions

Since the global financial crisis of 2007-2009, it has been widely recognized that financial stability should be monitored carefully using macroprudential policies. Demand-side policies that address household indebtedness by restricting mortgage lending have been implemented in several countries, including Finland. The aim of our analysis has been to shed light on the macroeconomic consequences of a recently proposed regulatory tool, the debt-to-income limit, and compare it with the existing regulation (*loan-to-value*) in the context of a dynamic general equilibrium model.

Our analysis lends support for the hypothesis that a *debt-to-income* constraint on mortgage loans could potentially have stabilizing effect on economy, especially when it comes to mortgage loans and house price inflation. The constraint would be particularly useful in booms, when asset prices increase. A pro-cyclical *loan-to-value* or *loan-to-collateral* constraints would relax in such situations and create a potential for an increase in mortgage loans and further increase the rise in housing prices. DTI limit is countercyclical in the sense that it would curb the household debt increase in a situation where house prices grow faster than income.

References

Akinci, O., and J. Olmstead-Rumsey (2018), How effective are macroprudential policies? An empirical investigation. *Journal of Financial Intermediation 33*, 33–57.

Andersen, A. L., C. Duus, and T. L. Jensen (2016). Household debt and spending during the financial crises: Evidence from Danish micro data. *European Economic Review 89,* 96-115.

Benigno, P., and M. Woodford. (2003). Optimal monetary and fiscal policy: A linear-quadratic approach. *NBER Macroeconomics Annual* 18, 271-333.

Bunn, P,. M. Rostom, J. Chadha, A. Chrystak, J. Pearlman, P. Smith, and S. Wright (2016). *Household debt and spending in the United Kingdom.* Cambridge University Press.

Cerutti, E., S. Claessens, and L. Laeven (2017). The use and effectiveness of macroprudential policies: New evidence. *Journal of Financial Stability 28*, 203–224.

Chen, J., D. Finocchiaro, J. Lindé, and K Walentien (2020). The cost of macroprudential deleveraging in a liquidity trap. *IMF Working Papers 89.*

Eickmeier, S., B. Kolb, and E. Prieto (2018). Macroeconomic Effects of Bank Capital Regulation. *Discussion Paper 44, Deutsche Bundesbank.*

ESRB (2019). *A review of macroprudential policy in the UE in 2019.* European Systemic Risk Board.

Grodecka-Messi, Anna (2020). On the Effectiveness of Loan-to-Value Regulation in a Multiconstraint Framework, *Journal of Money, Credit and Banking 52*, 1231-1270.

Ferrero, A., R. Harrison, and B. Nelson (2018). Concerted Efforts? Monetary Policy and Macro-Prudential Tools. *Bank of England Staff Working Paper No. 727.*

Gerali, A., S. Neri, L. Sessa, and F. M. Signoretti (2010). Credit and Banking in a DSGE Model of the Euro Area. *Journal of Money, Credit and Banking 42*, 107-141.

Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review* 95, 739-764.

Iacoviello, M. (2015). Financial business cycles. *Review of Economic Dynamics* 18, 140-163.

Iacoviello, M., and S. Neri (2010). Housing market spillovers: evidence from an estimated DSGE model. *American Economic Journal: Macroeconomics 2*, 125-64.

Justiniano, A., G. E. Primiceri, and A. Tambalotti (2015). Household leveraging and deleveraging. *Review of Economic Dynamics* 18, 3-20.

Kilponen, J., H. Kinnunen, and A. Ripatti (2006). Population ageing in a small open economy: some policy experiments with a tractable general equilibrium model. *Bank of Finland Research Discussion Paper 28/2006.*

Kilponen, J., S. Orjasniemi, A. Ripatti and F. Verona (2016). The Aino 2.0 Model. *Bank of Finland Research Discussion Paper No 16/2016.*

Kuttner, K. N., and Shim, I. (2016). Can non-interest rate policies stabilize housing markets? Evidence from a panel of 57 economies. *Journal of Financial Stability 26,* 31–44.

Kydland, F. E., P. Rupert, and R. Šustek. (2016). Housing Dynamics Over the Business Cycle. *International Economic Review 57,* 1149-1177.

Lim, C. H., Costa, A., Columba, F., Kongsamut, P., Otani, A., Saiyid, M., Wezel, T. and Wu, X. (2011). Macroprudential Policy: What Instruments and How to Use Them? Lessons from Country Experiences. *IMF Working Papers 11/238.*

Lainà, P., J. Nyholm, and P. Sarlin (2015). Leading indicators of systemic banking crises: Finland in a panel of EU countries. *Review of Financial Economics 24,* 18-35.

Mian, A. and A. Sufi (2010). Household leverage and recession of 2007-09. *IMF Economic Review 58,* 74-117.

Mian, A. and A. Sufi (2018). Finance and business cycles: the credit-driven household demand channel. *Journal of economic perspectives 32,* 31-58.

Mian, A., A. Sufi, and E. Verner (2017). Household debt and business cycles worldwide. *The Quarterly Journal of Economics 132, 1755-1817.*

Millard, S., M. Rubio, and A. Varadi. (2021). “The macroprudential toolkit: effectiveness and interactions.” *Bank of England Staff Working Paper, No. 902*.

Mokas, D., and M. Giuliodori (2021). Effects of LTV announcements in EU economies. *DNB Working Papers 704*.

Reinhart, C. M., and K. S. Rogoff (2009). *This time is different: Eight centuries of financial folly.* Princeton University Press.

Richter, B., M. Schularick, and I. Shim. (2019). The costs of macroprudential policy. *Journal of International Economics 118,* 263–282.

Rubio, M., and F. Yao. (2020). Macroprudential policies in a low interest rate environment. *Journal of Money, Credit and Banking 52*, 1565-1591.

Silvo, A., and F. Verona (2020). The Aino 3.0 model. *Bank of Finland Research Discussion Paper No. 9/2020*.

Tölö, E., H. Laakkonen, and S. Kalatie (2018). Evaluating indicators for use in setting the countercyclical capital buffer. *International Journal of Central Banking 14,* 51-112.

Verner, E. and G. Gyöngyösi (2020). Household debt revaluation and the real economy: Evidence from foreign currency debt crises. *American Economic Review 110,* 2667-2702.

Appendix

In this Appendix we provide some robustness checks for the main results introduced in the main text. We analyze the results under alternative parameter values and ensure that the results are not very sensitive for calibration of the model. We also provide further evidence on the results and display a fuller set of impulse responses to the shocks displayed in the main text. Some selected model moments are also computed and compared with the corresponding moments computed from the Finnish data over the period 1996Q1-2019Q4.

Model moments

To see how well the model captures the properties of the Finnish data, we report the model-implied moments for some of the central variables related to financial and housing markets in .The standard deviations of variables relative to the standard deviation of output (Y) are reported, as well as the contemporaneous correlations of variables with output. The moments are computed from the model with an LTV constraint in place. The parameter values are the same as in Silvo and Verona (2020), with the exception of the parameter j^I in impatient households' utility function, which has been set to a value of 0.355. Since the publication of Silvo and Verona (2020), there have been some minor corrections to the model and the computer code, and the aforementioned parameter has been reset in order to match the model's steady state mortgages-to-GDP ratio with the data.

Note that because of the corrections and the change in the value of j^I, the model-implied numbers in the table are not exactly the same as the ones reported in Silvo and Verona (2020). The moments computed from the data also slightly differ from the numbers reported in Silvo and Verona (2020). The reason for this is that in the original discussion paper, the series for output (Y) does not include the public sector, whereas in the figures presented in the table below it does.

Table 3. Moments of selected variables computed from the model and the data

	Std. dev. relative to std. dev. of Y		*Contemporaneous correlation with Y*	
Variable	**Data**	**Model**	**Data**	**Model**
Mortgage loan rate	4,58	1,15	0,44	0,37
Corporate loan rate	4,50	1,15	0,50	0,37
Mortgage loans	2,13	1,42	0,14	0,75
Mortgage loans-to-GDP	1,39	0,94	-0,61	0,07
Corporate loans	2,65	2,12	0,14	-0,08
Corporate loans-to-GDP	2,32	2,41	-0,33	-0,48
House price inflation	4,16	1,19	-0,26	0,74

The sample period is 1996Q1 – 2019Q4. The data are in de-meaned quarterly growth rates.

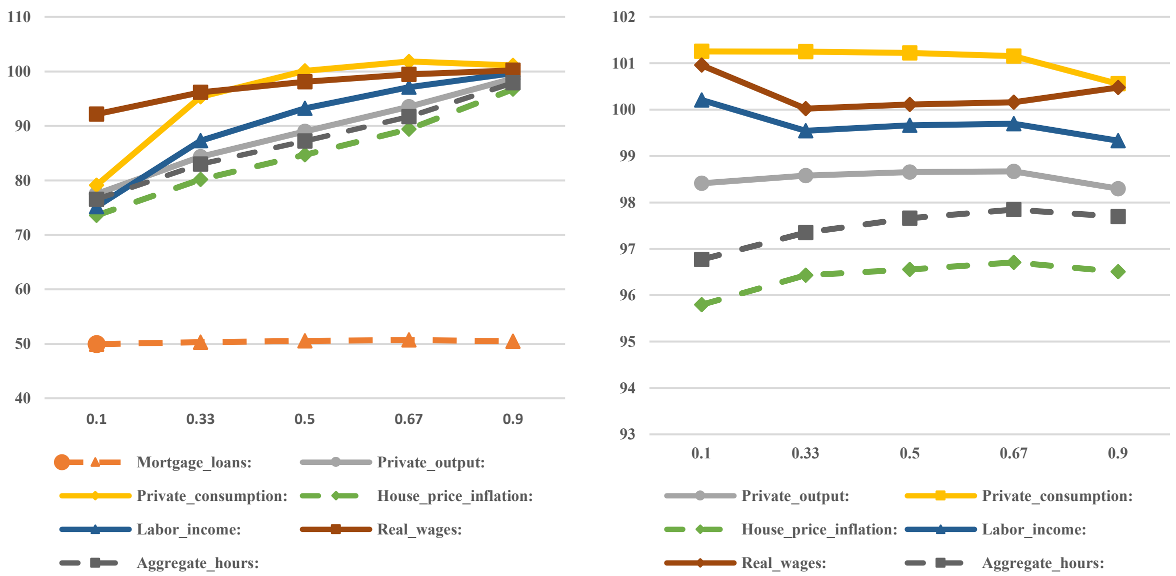
Change in the share of patient and impatient households

In the baseline calibration of the model, the share of the patient, or unconstrained, households isset to 67%, corresponding to *Finnish Household Wealth Survey data* (Silvo and Verona, 2020). The left panel in Figure 9 illustrates the evolution of the ratios of the standard deviations of the main macro variables as a function of the share of the patient households, ω_h. Not surprisingly, the larger is the share of the patient households, the closer the standard deviations get to each other, as the smaller gets the share of the population for whom the constraint is binding. Standard deviation of the mortgage loans to GDP gets smaller, as this share gets smaller in absolute value as well. This happens because the only smaller part of the whole population hold debt as the share on patient households increase. The main result holds robust. Real economy fluctuations are smaller under the DTI constraint, and the difference is the bigger, the greater share of the population is constrained.

Change in wage rigidity

Under the DTI constraint, labor income is the key variable for constrained households. First, it can be used to purchase consumption goods and housing. Second, it relaxes the borrowing constraint and allows households to acquire more mortgage loans and buy housing good. In the right panel of Figure 9 we display the model implied standard deviations of some of the macro variables under the DTI constraint, relative to those under the LTV constraint, against different degrees of wage rigidity in the labor market. Not surprisingly, the standard deviation of wages and labor income increases in DTI case more than in the LTV case, when the rigidity decreases (small values of Calvo wage rigidity parameter ξ_w). Under the DTI constraint, households' incentives to adjust their labor supply become greater, as it increases their consumption possibilities more than just the amount that the income increases. Changes are rather minor, however, and our results are not sensitive to the assumption on the wage rigidity.

Figure 9. Standard deviations of the selected macro variables under the DTI constraint, relative to the standard deviations under the LTV constraint, for different shares of patient households (left) and different levels of wage rigidity (right)



Changes in variances of shock processes

The type of the constraint matters for the variability of the variables after specific shocks. For example, in Figure 2 we saw, that a banking sector shocks impose more volatility in the economy under the LTV constraint. In Figure 10 we provide further analysis on this phenomenon. In the left panel of the figure, we study the effect of increased volatility in the banking sector. First, we increase the standard deviation on banking sector shocks until the standard deviation of the house price inflation has increased by 15%.[14] Low variance means the baseline calibration of the model and this new calibration is denoted by high variance. The lines depict how the standard deviation of a particular variable under the DTI regime, relative to LTV regime, changes when moving from low to high variance setting. If the banking sector would get more volatile, the analysis suggests that variability in mortgage to GDP, private output, house price inflation and aggregate working hours would increase more under the LTV constraint relative to DTI case.

The middle panel displays similar inspection, if the standard deviation of the labor supply shock increased such that the standard deviation of the aggregate working hours increased by 15%. In this case, the variance of these variables would increase more in the DTI case relative to the LTV case, although the difference is almost negligible.

In the last panel of Figure 10 the high variance setting is due to increased variance in capital and labor productivity. The increase has been calibrated such that the standard deviation of

[14] *To be more precise, the shocks whose variance was increased are a shock to bank capital, a shock to mark-up on NFC loans, a shock to mark-up of housing loans, and a shock to mortgage risk weights. The exact definitions of these shocks can be found in Silvo and Verona (2020).*

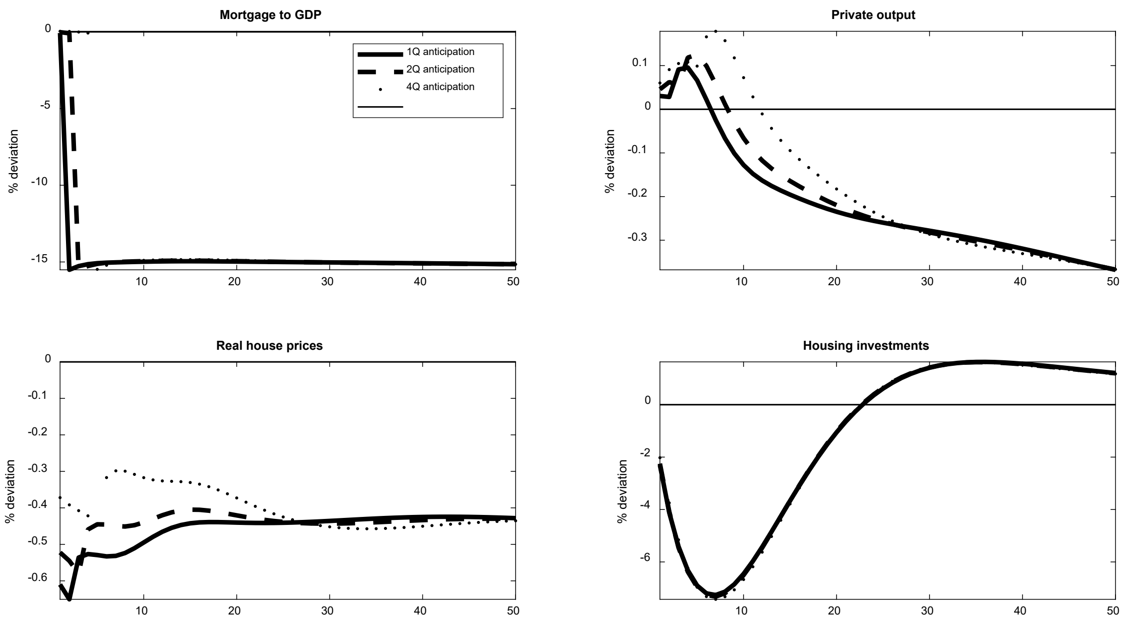
the private output would increase about 15%. The result is very similar to the previous case. The increase in variability in the economy would be approximately the same, no matter which constraint was in place.

This analysis provides support for our previous conclusions. The DTI constraint is more successful in harnessing the turbulence that is originated from the financial sector and implemented in interest rates. Other shocks that do not affect the interest rates, or the relative prices of consumption and housing goods, propagate to the economy with about the same force.

Figure 10. Standard deviations of certain variables under the DTI constraint, relative to their standard deviations in LTV case, in low and high variance settings

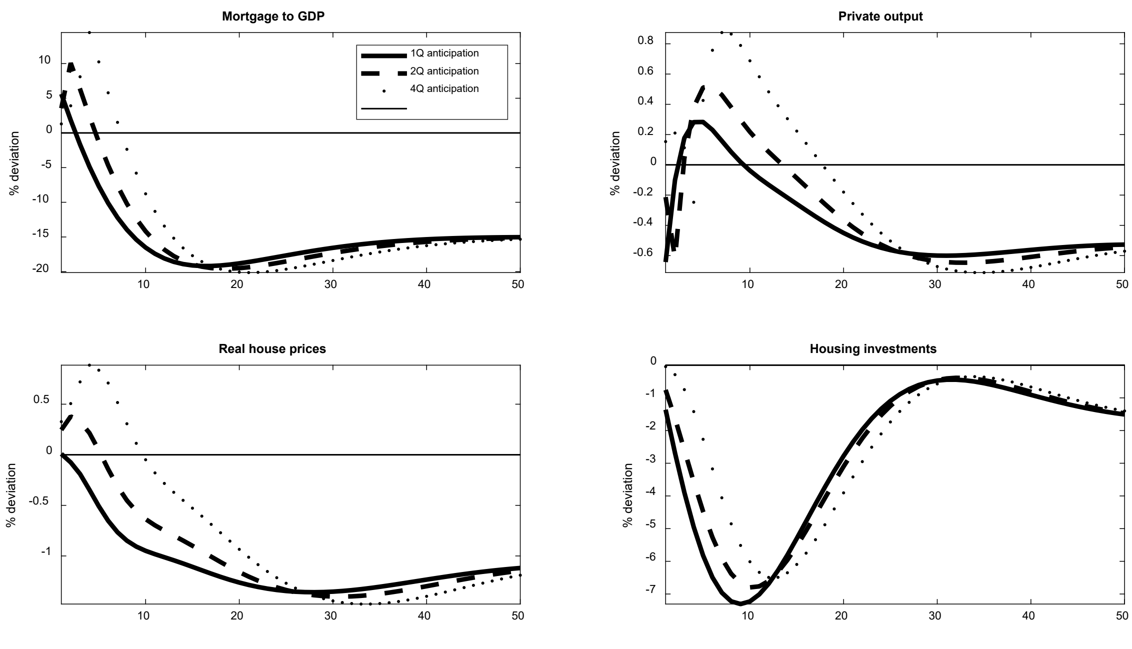
Additional figures

Figure 11. Impulse responses of an anticipated macroprudential shock under the DTI constraint



Impulse responses have been calculated using three different anticipation horizons, 1, 2, and 4 quarter.

Figure 12. Impulse responses of an anticipated macroprudential shock under the LTV constraint



Impulse responses have been calculated using three different anticipation horizons, 1, 2, and 4 quarter.

Figure 13. Impulse responses to a housing loan mark-up shock under LTV and DTI constraints

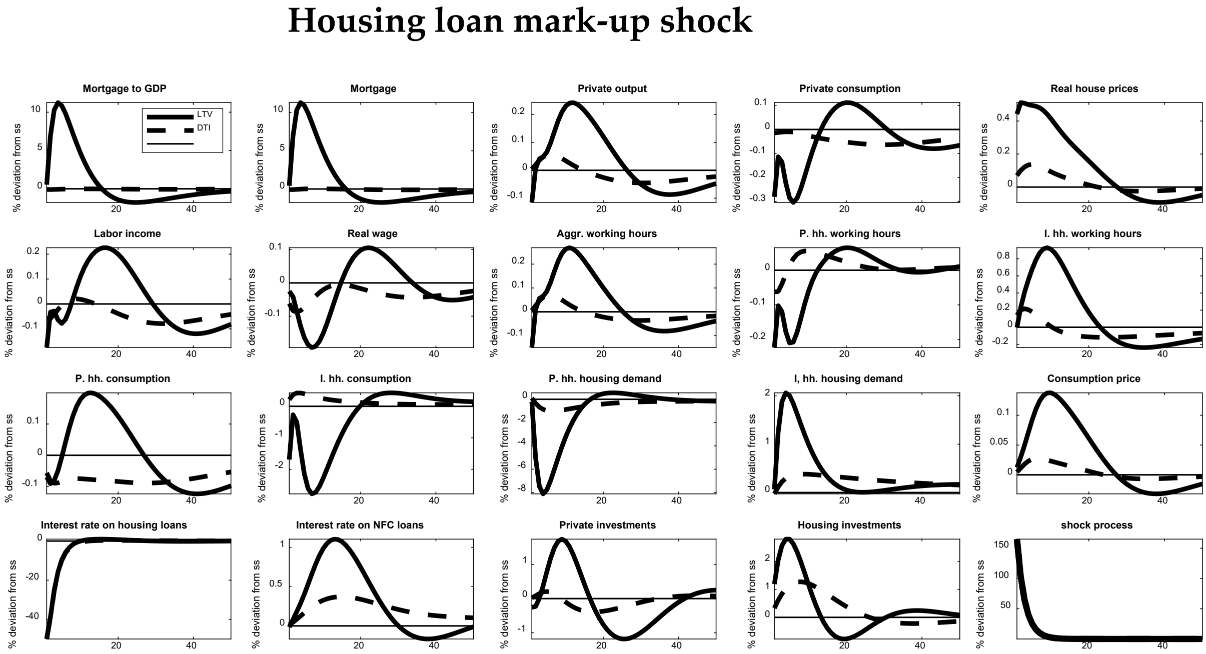


Figure 14. Impulse responses to a housing consumption preference shock under LTV and DTI constraints

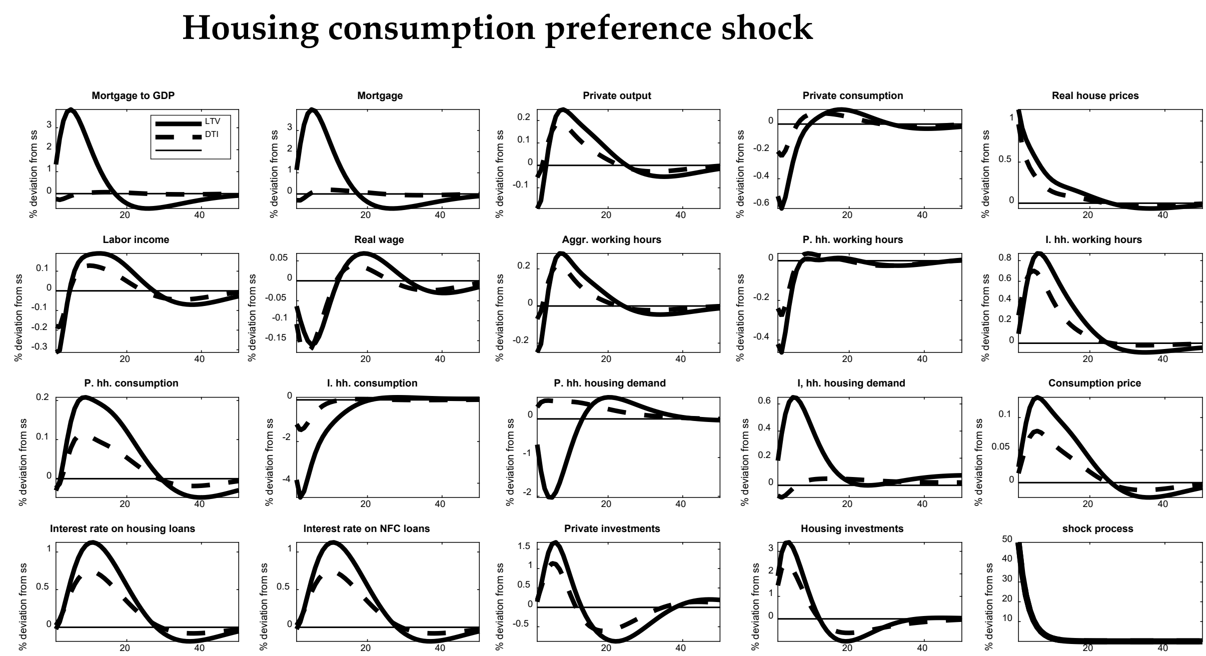


Figure 15. Impulse responses to a government consumption share shock shock under LTV and DTI constraints

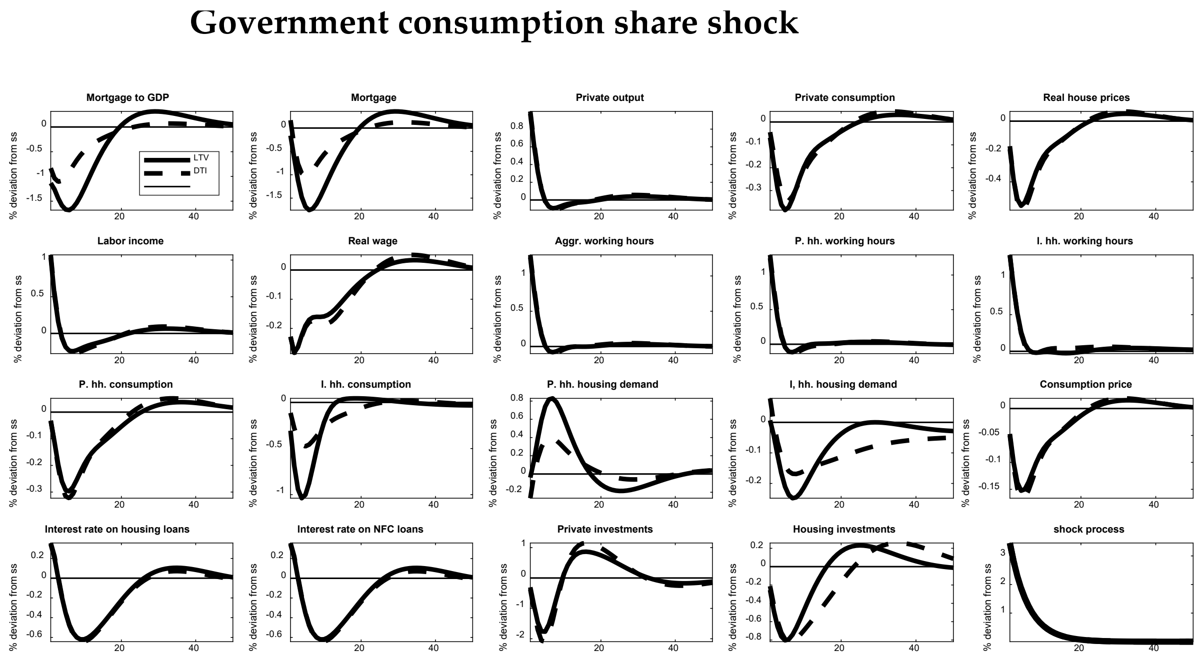


Figure 1. Impulse responses to a Euro area interest rate shock under LTV and DTI constraints

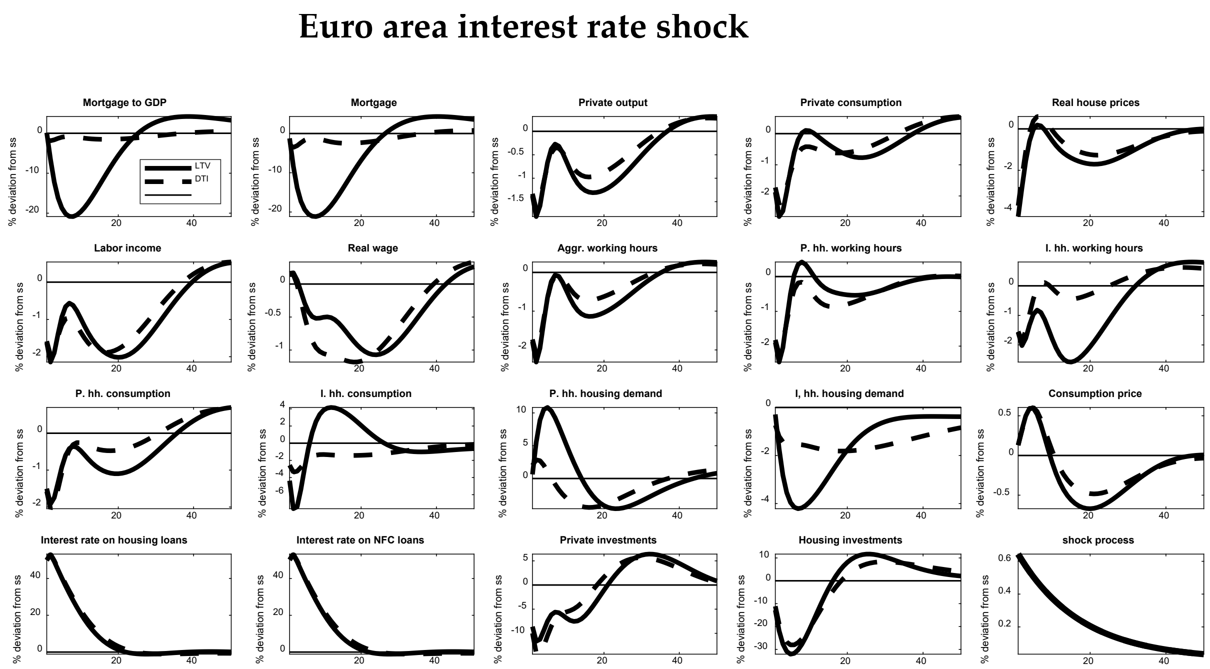


Figure 17. Impulse responses to a permanent anticipated macroprudential policy shock under LTV and DTI constraints