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# Financial shocks and their effects on velocity of money in agent-based model

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**Abstract**: The interaction of debt and economic performance has been getting more attention over the last few years. However, models making provision for debt are still outnumbered by models completely ignoring it. This paper is the first one to analyze the relationship between household debt (in the form of bank loans) and economic performance (in terms of aggregate income) considering both the impact of wealth and income distribution, and the impact of the MPC distribution under various financial shocks. The outcomes of the model are velocities calculated as ratios of aggregate income to aggregate debt. The paper demonstrates how financial shocks affect the income velocity of money under different distributions of wealth/income and marginal propensity to consume across the population. For this purpose, an original agent-based simulation model with a limited loan supply was designed. Proposed model shocks are shocks to loan demand, loan supply, marginal propensity to consume, macro-prudential regulatory ratios, real estate capital gains, repayment ratios, shocks to the structure of loans provided and to the structure of real estate property transactions. It is shown that the more equal the distributions of wealth/income and of the marginal propensity to consume, the higher is the income velocity of money. From financial shocks, the marginal propensity to consume shock and the shock to the structure of new real estate property purchases have the largest impact on velocity. The shock to regulatory ratios has generally the lowest magnitude.

**Keywords**: velocity of money, wealth distribution, marginal propensity to consume, financial shocks

**JEL Classification**: E510, E410, G510

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## Introduction

The reality of the last decades shows us that debt has an important place in modern economies. It has been proven that debt (particularly mortgage loan debt) affects economic performance in terms of aggregate income, consumption or growth. While the interaction of debt and economic performance has been getting more attention over the last few years and there have been some interesting papers published recently, the investigation of the relationship between the monetary and the real economy is still insufficient. Especially the in-depth transmission of monetary (financial) shocks to the real economy deserves

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more attention. The income velocity of money (further velocity of money or just velocity) is an ideal tool to investigate the relationship between debt and aggregate income, and to interpret the transition of financial shocks into the real economy, because velocity interconnects the monetary and the real economy in its deepest nature. Money, commonly defined as monetary aggregates[2], and debt are the opposite sides of the same coin and can be treated as equal under certain assumptions. This paper presents an original simulation model providing fairly complex insights into the loan-creation process and decision-taking actions of households (economic agents), simulating the impact of several financial shocks under the situation of different distribution of wealth/income and marginal propensity to consume, where loan supply is limited by macroprudential factors.

The aim of the paper is to analyze the impact of various shocks (to loan demand, loan supply, marginal propensity to consume, macro-prudential regulatory ratios, real estate capital gains, repayment ratios, to the structure of loans provided and to the structure of real estate property transactions) on the income velocity of money. The impact of the shocks is analyzed in different scenarios, which are the combinations of wealth/income distribution and the distribution of marginal propensity to consume (MPC) across the population of agents. This comprehensive analysis was not conducted before in this area of economics and I believe the findings fill the missing gap in the literature on velocity, wealth/income distribution and MPC distribution. To the best knowledge of the author, the model presented in this paper is the first one to analyze the relationship between household debt (in the form of bank loans) and economic performance (in terms of aggregate income) considering the impact of wealth and income distribution, and the impact of the MPC distribution under various financial shocks. The outcomes of the model are velocities calculated as ratios of aggregate income to aggregate debt.

The analysis shows that velocity reaches the highest levels when the marginal propensity to consume is distributed equally and when wealth/income is distributed equally. Velocity decreases with increasing inequality of wealth/income and MPC inequality. The MPC shocks and the shocks to the proportion of new real estate property purchases have the largest impact on velocity. The shock to regulatory ratios has the lowest magnitude – its impact is practically zero, except for the scenarios with a uniform MPC distribution where some agents are willing to consume more than they can afford, but are not provided additional loans due to macroprudential constraints.

The paper is divided into four main sections – Theoretical background, summarizing literature overview on relevant topics to prepare the background for the model design; Model part describing the suggested model, its variables and interactions between agents; Results where simulation results are presented and interpreted; and Conclusion where main findings are summarized.

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[2] Monetary aggregates are part of the national monetary survey and are calculated as aggregated balances of monetary financial institutions (banks) where money is defined as cash plus various deposits. Money (on the asset side of banks) is originated by net domestic assets (various debt instruments provided to domestic residents) and by net foreign assets (balance of financial claims and liabilities in relation to non-residents).

## Theoretical background

*The level of debt has consequences for economic growth*

There is an increasing number of studies about how household debt, which appears to consist mostly of mortgage loans, impacts future economic growth. The theory of indebted demand (Mian, Straub and Sufi 2020) indicates that households' indebtedness lowers future aggregate demand. Bahadir, De and Lastrapes (2020) show household debt may result in increased consumption in the short-term but at a cost of reducing aggregate consumption in the long term. Schularick and Taylor (2012) show, investigating 14 countries over years 1870–2008, that credit growth is a strong predictor of financial crises, which are generally coupled with declines of aggregate consumption and aggregate income. Alter, Feng and Valckx (2018) confirm the negative relationship between household debt and future GDP growth using a set of countries over years 1950–2016. Jorda, Schularick and Taylor (2016) emphasize the importance of housing finance and real estate cycles in modern macroeconomy. They also manifest that mortgage and non-mortgage lending is a possible predictor of financial crises. Dynan (2012) claims that household debt issues were given little attention before the 2007–2009 crisis and that high levels of debt with regard to (falling) real-estate prices tend to depress aggregate consumption.

It is possible to refer to this state of high indebtedness in relation to the value of assets as "debt overhang", which can be generally described as a situation where the level of debt is so high that creditors do not expect with confidence the debt will be fully repaid" (see Krugman 1988). Then, "debt overhang hypothesis" may be generally defined as a situation where debt overhang has negative implications for economic growth (see Myers 1977 for the origins of debt overhang hypothesis). Dynan (2012) suggests there are two reasons why high levels of debt negatively influence consumption: if households target a certain leverage ratio, their response to asset prices fall is to lower consumption. Secondly, banks are more reluctant to lend to highly indebted applicants. On the contrary, when asset prices rise, households tend to increase their spending through a wealth channel. Mian (2012) proposes three channels through which high debt influences real outcomes: investment channel (drop of investment), bank lending channel (financial intermediaries' asset value drops and they become unable to lend as much as before), and consumption channel (fall of asset prices leads to lower consumption). Focusing on the external debt of developing countries, Daud and Podivinsky (2012) found that a rise in external debt is negatively linked to economic growth. By analyzing 28 EU countries, Vanlaer, Picarelli and Marneffe (2021) confirm that the debt overhang hypothesis holds for public debt, but not for private investment.

*Velocity of money*

As can be understood from the abovementioned, the linkages between debt and economic growth are important to formulate macroeconomic policies – either fiscal policy with regard to external public debt or – more importantly for the needs of this paper – macroprudential policy with regard to loans provided by the domestic banking sector (primarily mortgage loans). A reasonable level of debt may benefit overall economic performance. However, excessive debt may become a disastrous burden. This is a task for policymakers to set the right prudential measures to prevent the debt overhang situation (Daud and Podivinsky 2012).

But the question is – how should we assess the relationship between debt and economic performance (say, in terms of aggregate income)? One of the most crucial problems is that additional debt may lead to increased consumption and aggregate income, but the opposite direction is also possible – additional income may lead to additional consumption and new debt. This apparent endogeneity may be overcome by using the velocity of money, because velocity does not treat debt (respectively money, as will be shown) and aggregate income separately. Instead, velocity is the expression of this relationship itself. This makes the velocity of money a powerful tool to describe the relationship between debt and aggregate output.

In general, velocity indicators are ratios of flow variables (such as aggregate income over one year) to stock variables (such as household liabilities at the end of the year). If we put an equal sign between loans provided by the domestic banking sector and the change of money stock, the velocity of money and the velocity of loans may be considered equal. The assumption of money being equal to loans provided by the domestic banking sector is not far from reality because in general, money and debt are two sides of the same coin (Xing et al. 2018). One cannot really understand money without debt and vice versa. In order to be precise, the following assumptions are necessary to put the equal sign between loans and money: a) the banking sector does not buy or sell existing assets from non-bank economic agents[3]; b) banks do not issue long-term debt or equity instruments; and c) domestic residents do not lend domestic deposits to foreign residents (i.e., the change of net foreign assets is zero) (McLeay, Radia, Thomas 2012).

The velocity of money had been at the centre of monetary theories for many decades (Humphrey 1993). Probably the most renowned version of velocity can be found in Irving Fisher's exchange equation, MV = PY, where M is the total stock of money, V is the circulation velocity of money, P is the average price level and Y is the total output (I. Fisher, 1922). Other renowned arguments about velocity may be found in the work of monetarists (e.g. Friedman, 1986) who influenced the actual conduct of monetary policy.

There are many ways how to interpret the velocity of money. Post Keynesian monetarists seem to interpret velocity in terms of a nominal credit expenditure multiplier. The multiplier is calculated as the addition to aggregate nominal demand ($dY_t$) resulting from an additional dollar change of credit ($d\Delta D_t$). Palley (2014) defines the nominal credit expenditure multiplier $v_t$ as:

$$v_t = dY_t / d\Delta D_t$$

This is an expression based on a Keynesian multiplier. The concepts of the velocity of money and multiplier are close, as demonstrated in Wang, Xu and Liu (2010). They show that the velocity of money and the Keynesian multiplier are proportional and that it is possible to study the velocity of money without mentioning the multiplier. This being said, we can understand the velocity as the ratio of how much aggregate nominal demand increases given the change in debt. The increase in velocity then indicates that additional credit brought more than a proportional increase in aggregate nominal demand and vice versa. This makes the velocity a great tool to analyze the impacts of increased debt on

[3] E.g., banks do not buy or sell domestic currency or bonds issued by domestic non-financial corporates.

aggregate income (AD). However, as mentioned before, the relationship between debt and AD is not one-way. Not only does debt impact AD, but also AD impacts debt. Velocity as a mean of assessing the relationship between the two is nevertheless still intact because it does not rely on any causal relationship.

There are a few further issues connected to velocity worth mentioning. Certain periods, specifically the early 1990s, were characterized by rising velocity and became known as the period of “missing money” (a term used by S. Goldfeld, Fand and Brainard in 1976). On the other hand, the later 1990s and forthcoming years could be characterized by the period of “excessive money”. Despite a few deviations, there had been a 20-year period of velocity decline in EMU countries. Some of the possible explanations involve the theory of increasing demand of real GDP for the volume of money, and the theory of increasing importance of new financial products not directly linked to GDP to money transfers (Arlt et al. 2001). Moreover, larger portion of loans is provided for non-productive purposes in terms of GDP, such as trades of already existing real estate property assets. Jilek (2015) also summarizes that low-inflation countries were characterized by a negative correlation between monetary growth and velocity. Nevertheless, I believe these obstacles may be overcome if treated properly by a model complex enough.

*Money and debt in economic models*

Money is rarely incorporated in the conduct of today’s monetary policy. This is due to the unpredictability of the impacts of monetary aggregate changes on price stability and economic output, together with the inability of central banks to control monetary aggregates. Money is neglected especially under the inflation targeting regime, which resigns to a narrowly set transmission mechanism. Instead of monetary aggregates, inflation targeting focuses rather on interest rates policy (Rochon, Rossi 2006; Woodford 2008). Mainstream macroeconomists prefer to ignore debt (Borio and Lowe 2004; Xiaoyun 2018), money is mostly treated only as a medium of transaction and economic agents do not take decisions based on their money holdings. Even if credit market is mentioned, the attention is put on the interest rate rather than on the credit stock and flow (Godley and Lavoie 2012).

Nevertheless, there are authors trying to incorporate money or debt into their models. Xiong, Fu and Wang (2017) propose an agent-based model to depict the dynamic process of money creation and money circulation in a credit economy, with an emphasis on repayment behavior. The find velocity is affected by agents’ repayment behavior, propensity to spend and by banking sector reserve requirements. Berentsen, Marchesiani and Huber (2016) suggest that taking account of lending limits helps to explain the relationship between GDP and monetary stock. Berentsen (2000) shows that the marginal value of money decreases with the quantity of money held; and that there is an upper bound for money holdings. Boyao and Wang (2020) examine the money creation and destruction process using an integrated stock-flow approach. According to their research, higher policy rates may lead to increased output; and the central bank supplying banks with additional reserves may cause output to decrease. Kiyotaki and Moore (1997) investigated the dynamic interaction between credit limits and asset prices, showing that shocks to income distribution may create persistent fluctuation of output and asset prices.

*Wealth/income distribution and distribution of MPC*

As stated earlier, changes of aggregate liabilities have an impact on aggregate income and on the income velocity of money. The changes of liabilities are, however, far from being the only factor that influences the income velocity of money (Humphrey 1993). The transmission from changes in liabilities to changes in output is not straightforward (Marcuzzo 2017). One of the important factors that affect how new money is used in the income-consumption process and how the velocity evolves is the distribution of wealth and income. The idea that the distribution of wealth affects velocity of money was first suggested by W. Petty in 1664 (Humphrey 1993). Petty's example is very simple in keeping only two groups in his model. The richer group has lower velocity than the poorer one. Thus, when the proportion of the richer group increases, aggregate velocity decreases and vice versa. In the real world, there are many agents, each of them having their own velocity and income. To capture this notion, it is possible to estimate the wealth/income distribution of the whole population. Generally, we are interested in the mean of the distribution – in the average wealth/income; and in the dispersion of the distribution – inequality.

The rising share of income earned by the top of the income distribution has been documented (e.g., Piketty, Saez, and Zucman 2018). Mian, Straub and Sufi (2020) show that the rise in top income shares began in the 1980s, together with the rise in government and household borrowing, and that the patterns are closely linked. Bahadir, De and Lastrapes (2020) quantify the link between inequality and aggregate consumption change due to an increase in household liabilities using a simple dynamic model. According to them, countries with a relatively more unequally distributed income experience larger long-run declines of spending. Pinkovskiy and Sala-i-Martin (2009) provide more empirical findings on the distribution of income.

Another important issue, tightly connected to the distribution of income, is the existence of differences in the marginal propensity to consume (respectively marginal propensity to save) among households. The changes in the distribution of income affect aggregate demand and velocity, primarily because MPC depends on wealth or income. This way, the changes in the distribution of income alone, independently of new borrowing or debt repayment, may cause changes to aggregate income and velocity (Palley 2014). It is typically assumed in economic models that either a) debtors and creditors (savers) have different MPC or that b) MPC functionally depends on wealth or income.

The assumption of non-homotheticity means that savers save a larger part of their income than borrowers (Mian, Straub and Sufi (2020). According to Palley (1997), there are several possible justifications for non-homotheticity: a) Keynes's psychological law – if creditors have a relatively greater income than debtors, creditors have on average smaller MPC; b) Kaleckian justification – MPC out of wage income is higher than MPC from profit and interest income (which is concentrated in lenders' hands); and c) overlapping-generations model – if young generations, which are primarily debtors, have higher MPC, then debtors will on average have higher MPC (Palley 1997).

The existence of differences in saving rates across the wealth or income distribution has been empirically verified in recent papers. Based on Norwegian data, Fagereng et al. (2019) found that saving rates are strongly increasing with increasing *income*; saving rates net of capital gains are approximately constant across the *wealth* distribution; and saving rates including capital gains increase with *wealth*. Wealthier households' dominant assets are real estate properties, and their dominant source of wealth accumulation are capital gains. By not selling their real estate assets, they experience persistent capital gains (the authors call this phenomenon "saving by holding"). Bach, Calvet and Sodini (2018) prove on Swedish data that the saving rate, defined as saving from labor income divided by net worth, is a decreasing function of net worth.

Alter, Feng and Valckx (2018) state that MPC is higher for poorer borrowers. Moreover, highly indebted low-income households must reduce consumption when negative income shocks hit. Based on a microeconomic studies overview, Caroll et al. (2017) conclude that annual MPC out of one-time income shocks is significantly larger for low-wealth households. He also finds that the annual MPC out of shocks to liquid assets is higher than the MPC out of shocks to illiquid assets. Kumhof, Ranciere and Winant (2015) find that saving rates are a steeply increasing function of income.

## Model

The model framework is designed to capture the economic interaction between agents in a closed economy to analyze the effects of shocks on the income velocity of money (velocity). Non-bank agents (households) demand loans from banks and use them for consumption and real estate purchases. Banks serve only as providers of loans to the system and they themselves do not consume nor invest. Neither government nor taxes are considered. The amount of loans provided is determined by the interaction between loan demand and supply. Part of the loan demand is not satisfied by the supply side, because banks are risk-averse and provide loans only to creditworthy loan applicants. Creditworthiness is evaluated in terms of two indicators – loan-to-value (LTV) and debt-service-to-income (DSTI), for which regulatory macroprudential limits exist, but banks may apply stricter thresholds than the regulator. Moreover, loan demand and loan supply are sensitive to the macroeconomic sentiment. Outstanding loans are repaid over time. No distinction between nominal and real variables is made and inflation is not present in the model. The economy is closed so aggregate income equals aggregate consumption plus aggregate investment given by new real estate property purchases. Therefore, increased consumption and income in one period translates into increased income in the following one.

The income velocity of money is defined for each period as the ratio of aggregate income to outstanding loans, as money is created solely by loan creation. The assumption that money is created only by loan activity is used in the model since we assume a closed economy and the other way of money creation – the change of net foreign assets – can only happen in an open economy. The shocks to the model include shocks to loan demand, loan supply, regulatory ratios (LTV and DSTI), repayment ratios, real estate prices and MPC. Moreover, the structure of loans provided and the structure of real estate property transactions are subject to shocks.

The dynamics of the model is primarily given by new loans provided. It is assumed that once provided, mortgage loans are drawn fully, and no advance payments are allowed. Whenever new loans are provided, new money starts circulating throughout the system. New loans may be provided for two main motives. The first motive centers around consumer loans. Consumer goods purchases financed by consumer loans are typically part of the gross domestic product (GDP). Under the second motive, agents demand mortgage loans to purchase real estate properties. Real estate property sales are divided into a) sales of new RE properties and b) sales of already existing RE properties. Existing property sales themselves do not immediately increase GDP. On the other hand, new property sales contribute to GDP as they are considered part of the aggregate investment.

Immediate consequences of RE property sales are primarily monetary – aggregate loans increase, and aggregate money balances increase. This happens both in the case of new and existing RE property sales. In the case of new RE property sales, GDP increases significantly while in the case of existing property sales, GDP increase little or not at all (this depends on the value added created during the real estate sale intermediation process). The transaction has also a short- to medium-term impact on flow variables (particularly on consumption and income). By creating new money, new purchasing power was created in the economy. Although it is possible, the original seller probably would not use the money obtained from the sale to buy another property. Instead, it will be assumed the money he receives from the sale can be either used for consumption, repayment of his liabilities or saved. Generally, the money will be partially spent for consumption and partially saved, where the proportion of consumption (saving) is given by the marginal propensity to consume (save) out of disposable income and wealth. If an agent saves all the money he received from the sale, the process stops. However, if the agent consumes at least some amount, the spent money migrates to another agent and the consumption process continues, further increasing the aggregate consumption. A notion of a consumption multiplier is apparent here – the initial rise of mortgage loans may lead to increased consumption, and thus to increased aggregate output. The multiplication effect is larger, when (ceteris paribus): 1) the amount of provided loan is higher; 2) the time period between consumption is smaller; 3) the MPC of agents involved in the consumption process is higher. Let us elaborate on these points in more detail.

The logic behind the first factor is straightforward – the higher the amount of provided loan, the more can be spent at initial trade, and, at the same time, more can be spent in the aftermath. Banks define constraints on the amount of loans provided. These constraints typically include *loan to value* (LTV) or *debt service to income* (DSTI) ratios. Agents with more assets and/or disposable income are typically able to approach higher loan amounts because they imply less risk than agents with less wealth. Households with relatively higher disposable income are more capable of fulfilling the DSTI constraint and households with relatively more financial and non-financial assets are more capable of fulfilling LTV. Moreover, higher real estate prices lead to higher mortgage loan amounts and, through the multiplication effect, to higher consumption. In case of rising property prices, LTV does not restrain loan supply, but DSTI does if property prices increase at a higher rate than disposable income.

The length of the time period between spending is more of a technical category, but it is important to mention. It is naturally not the same whether an agent uses her newly acquired money immediately or after one year. If the time period is infinitely small, all effects occur immediately. On the other hand, if the period is too long, the effects might not occur in full over the selected period. This happens if the observation period is shorter than the interval between spending. If real time is not considered in a model, this issue can be considered irrelevant.

Higher MPC has a positive effect on consumption. As mentioned in the previous parts, selected papers prove differences in MPC between creditors and debtors or differences based on wealth or income. Therefore, higher wealth or income may lead to lower MPC, and thus to lower consumption. Note that the effect of wealth has an opposite direction to the effect described in the previous point.

The velocity of money should be understood as the ratio of aggregate income to money stock. Whenever new loans are provided, the velocity is prone to change. The change of velocity from time *t* to *t+n* is then defined as:

$$\Delta V^{t,t+n} = \frac{\Delta YD^{t,t+n}}{\Delta M^{t,t+n}} \tag{1a}$$

On one hand, the numerator may change – the aggregate income (*YD*) increases if at least some part of the newly created money is used for consumption – this happens always in the case of consumer loans. YD also rises when newly built real estate properties are sold (i.e., whenever a new mortgage loan for a new RE property sale is provided). Lastly, YD rises as a consequence of increased consumption after the RE purchase in the case of all mortgage loans. On the other hand, the denominator changes – the money stock is increased by $\Delta M$ (respectively by $\Delta L$ under the assumption $\Delta L = \Delta M$). By taking the possibility of loan repayment into account, the change in the money stock is calculated as the loan stock at time $t+n$ minus the non-repaid amount of initial loan principal at time *t* where ($K_{pr}$) is the amount of repaid principal. As for the numerator, in a closed economy, aggregate output is equal to aggregate consumption plus aggregate investment (represented by sales of new RE properties). The change of velocity from time t to *t+n* is then:

$$\Delta V^{t+n} = \frac{\Delta C^{t,t+n} + \Delta I^{t,t+n}}{L^{t+n} - L^{t} - K_{pr}^{t}} \tag{1b}$$

Consumption and investment certainly do not decrease after new loans are provided (ceteris paribus).[4] The reason is that a new loan brings additional money flowing to the economy, and the money may be spent in the consumption process repeatedly as it passes from one consumer to another until repaid. The magnitude of the overall change in consumption and investment given by the initial shock is difficult to measure as the overall change is affected by numerous variables. This paper examines how velocity changes in response to a range of shocks. The shocks to the model are defined as positively (negatively) correlated series of shocks to: a) loan demand; b) loan supply; c) regulatory ratios of LTV and DSTI; d) repayment ratios; e) real estate prices; f) change in the structure of loan demand; g) MPC; and h) the ratio of new RE property transactions to all RE property transactions. The shocks are defined so as to observe the impact of the most important fundamental changes on the velocity of money. A simulation consisting of *N* agents (each noted *i*) and *T* discrete time periods (each noted ***t***)[5] is run under 16 different scenarios

[4] Note that depreciation of investment assets is assumed to be zero.

[5] For simplification, both stock and flow variables are noted with upper index *t* (respectively *t-1* or *t+1*). For flow variables, *t* means “over selected period” and for stock variables, *t* means “at the end of selected period”.

representing different combinations of wealth/income distribution and MPC distribution, to which the shocks are applied.

The model consists of the following set of equations:

*Consumption*

$$C_{full,i}^{t} = \alpha_{1i} YD_i^t + \alpha_{2i} W_i^{t-1} + \Delta LC_{gross,i}^{t} \tag{2a}$$

$$C_{real,i}^{t} = min\{C_{full,i}^{t}; AF_i^t + YD_i^t + \Delta LC_{gross,i}^{t} - K_{real,i}^{t}\} \tag{2b}$$

*Repayment*

$$K_{full,i}^{t} = LC_i^{t-1} * k_{LC} + LNF_i^{t-1} * k_{LNF} \tag{3a}$$

$$K_{real,i}^{t} = min\{K_{full,i}^{t}; AF_i^t + YD_i^t\} \tag{3b}$$

*Wealth*

$$AF_i^t = AF_i^{t-1} * (1 + r_{AF}^t) + YD_i^t - \left(C_{real,i}^{t} - \Delta LC_{gross,i}^{t}\right) - K_{real,i}^{t} \tag{4a}$$

$$ANF_i^t = ANF_i^{t-1} * (1 + r_{ANF}^t + \Delta p_{ANF}^t) + \Delta LNF_{gross,i}^{t} \tag{4b}$$

$$W_i^t = ANF_i^t + AF_i^t \tag{4c}$$

*Loan structure and development*

$$\Delta L_{gross,i}^{t} = \Delta LC_{gross,i}^{t} + \Delta LNF_{gross,i}^{t} \tag{5a}$$

$$L_i^t = LC_i^{t-1} + LNF_i^{t-1} + \Delta L_{gross,i}^{t} - K_{real,i}^{t} \tag{5b}$$

$$LC_i^t = LC_i^{t-1} * (1 - k_{LC} * \frac{K_{real,i}^{t}}{K_{full,i}^{t}}) + \Delta LC_{gross,i}^{t} \tag{5c}$$

$$LNF_i^t = LNF_i^{t-1} * (1 - k_{LNF} * \frac{K_{real,i}^{t}}{K_{full,i}^{t}}) + \Delta LNF_{gross,i}^{t} \tag{5d}$$

*Aggregate income and monetary stock*

$$\Delta YD^t = \sum \Delta C_{real,i}^{t} + \sum \Delta LNF_{gross,i}^{t} * \rho \tag{6}$$

$$\Delta M^t = \sum \Delta L_i^t \tag{7}$$

$$\Delta YD_i^{t+1} = distribution(YD^t - YD^{t-1}) \quad (8)$$

*Loan demand and supply*

$$\Delta L_{i,\boldsymbol{D}}^{t+1} = (1 + \psi_D^t) * [\varphi_1 * (\alpha_{1i} YD_i^t + \alpha_{2i} W_i^{t-1}) + \varphi_2 * W_i^{t-1} - \varphi_3 * \Delta r_i^t] \quad (9)$$

$$\Delta L_{i,S}^{t+1} = (1 - \psi_B^t - \psi_S^t) * \left( min \left[ \Delta L_{i,D}^{t+1}; max \left\{ \frac{ltv_R * W_i^t - L_i^t}{(1 - ltv_R * \omega)}; 0 \right\}; max \left\{ \frac{dsti_R * YD_i^t - K_{full,i}^t}{(k_{LC} * \omega + k_{LNF} * (1 - \omega))}; 0 \right\} \right] + \varsigma * \Delta r_i^t \right) \quad (10)$$

$$\Delta LC_{gross,i}^{t+1} = \Delta L_{i,\boldsymbol{S}}^t * \omega \quad (11a)$$

$$\Delta LNF_{gross,i}^{t+1} = \Delta L_{i,\boldsymbol{S}}^t * (1 - \omega) \quad (11b)$$

*Technical equations*

$$AF_i^t = AF_i^t + distribution\left(\sum \Delta LNF_{gross,i}^t * (1 - \rho)\right) \quad (12a)$$

$$ANF_i^t = ANF_i^t - distribution\left(\sum \Delta LNF_{gross,i}^t * (1 - \rho)\right) \quad (12b)$$

*Velocity of money*

$$V^t = \frac{YD^t}{M^t} \quad (13a)$$

$$\Delta V^t = \frac{\Delta YD^t}{\Delta M^t} \quad (13b)$$

The simulation process is primarily driven by demand for non-financial assets (*ANF*) and consumption (*C*). To satisfy the demand for non-financial assets, agents apply for mortgage loans (*LNF*), and to satisfy the consumption demand, agents apply for consumer loans (*LC*). Once agents are granted a loan, they obtain non-financial assets (*ANF*) in case of a mortgage loan or financial assets (*AF*) in case of a consumer loan. By receiving a loan, agents' gross increase of liabilities is $\Delta L_{gross}$, which is the sum of the gross increase of consumer loans ($\Delta LC_{gross}$) and the gross increase of mortgage loans ($\Delta LNF_{gross}$). The proportion of the increase of consumer loans to the increase of total loans is noted $\omega$. The proportion of the increase of mortgage loans to the increase of total loans is then ($1- \omega$). This is captured by equations (5a), (11a) and (11b). Non-financial assets are represented solely by RE properties and financial assets are represented by current deposit holdings. Liabilities (*L*) consist of consumer loans and mortgage loans.

A crucial part of the model is the consumption equation (2a). The amount an agent wishes to consume is $C_{full}$. Agents consume from their current disposable income (*YD*) and from wealth (*W*), which is a standard Keynesian consumption function complemented with consumption from wealth. The idea of consumption from income and wealth is consistent with Godley and Lavoie (2012), Wang, Xu and Liu (2010) or Kumhof, Ranciere and Winant (2015). Moreover, agents use consumer loans ($\Delta LC$) to satisfy their consumption needs. It is assumed that consumer loan amounts are fully consumed, because agents take loans to spend money balances, not to keep them. On the contrary, at the moment of a real estate sale, mortgage loans do not contribute to the increase of consumption at all. In other words, immediate MPC from taking a consumer loan is assumed to be one; and immediate MPC from taking a mortgage loan is assumed to be zero. Repayments ($K$) decrease agents' financial assets ($AF$) and have the potential to decrease consumption. The term repayment stands for the payment of principal plus the interest, no separation between the two is made. Prescribed loan repayment $K_{full}$ is the prescribed repayment of the consumer loans outstanding at the end of the previous period at rate $k_{LC}$, plus the prescribed repayment of mortgage loans outstanding at the end of the previous period at rate $k_{LNF}$ (Eq 3a). In case the sum of the agent's disposable income and financial assets is less than the prescribed repayment amount, the agent repays less than the prescribed amount and the amount actually repaid is $K_{real}$ (3b). Similarly, in case the agent's desired consumption $C_{full}$ is higher than his actual financial resources, he spends the amount of his resources and his actual consumption is $C_{real}$ (2b).

Finally, consumption is given by the marginal propensity to consume with respect to disposable income ($\alpha_1$) and the marginal propensity to consume with respect to wealth ($\alpha_2$). One of the key model traits is that economic agents may have different marginal propensities to consume. It is not a new idea to economics that each individual may have a different MPC. To capture this notion, distributions of MPC within the population are constructed. Four different MPC distributions were applied, in which agents' MPC is a decreasing function of wealth (or in one case, all agents have the same MPC). The assumption of MPC decreasing with wealth is based on empirical evidence described in the *Theoretical background*. The simulation is run under sixteen (4x4) different scenarios. A detailed description of the scenarios and distributions can be found in part *MPC Scenarios*. As will be shown, the shape of the MPC distribution has an impact on aggregate consumption, income, and eventually on the velocity of money.

Equations (4a) and (4b) show how financial and non-financial assets evolve over period $t$. In general, financial assets of an agent $i$ increase when his consumption net of new loans is smaller than his disposable income. Financial assets also yield returns to their owner at a return rate $r_{AF}$. Non-financial assets yield rent at a return rate $r_{ANF}$ and capital gains at a rate $p_{ANF}$. Real estate asset depreciation is not considered (respectively, it is assumed that gross capital gains are never lower than depreciation). The total wealth of an agent ($W$) is the sum of her financial and non-financial assets (4c). When agent $i$ gets a mortgage loan, the value of her non-financial assets increases by $\Delta LNF_{gross}$. The outstanding amount of total liabilities $L$, together with the distinction into $LC$ and $LNF$ is defined in equations (5b-5d).

The change in aggregate income ($\Delta YD$) is equivalent to the sum of changes in individual consumptions and investments (newly produced RE properties) for a given period because one's consumption plus investment is another's income (Eq 6). The investment equals to the change of mortgage loans provided for the purchase of new RE properties, which is equal to the total amount of mortgage loans times the share of mortgage loans for new real estate properties on the total amount of mortgage loans ($\rho$). It is assumed that new real estate properties may be financed only by mortgage loans (i.e., not completely by agent's savings in terms of held financial assets) and that the change of other components of aggregate demand is zero. The change in aggregate monetary stock (*ΔM*) is the sum of the changes in all household liabilities (*ΔL*), which are consumer and mortgage loans (Eq 7).

The aggregate increase in disposable income ΔYD is distributed to all agents depending on their wealth based on a normal, lognormal, uniform, or equal distribution (Eq 8). This is because wealth has an impact on MPC, as discussed in the theoretical part. For more detail, see part *MPC Scenarios*. Disposable income (in absolute numbers) cannot be less than zero for any agent.

Equation (9) defines loan demand. The volume of demanded loans increases with wealth and income (and thus by consumption as well); and with MPC – it is assumed that agents with higher MPC demand relatively more loans. Keeping in mind that richer agents have on average lower MPC, loan demand generally increases with wealth, but at a slowing rate. Changes in loan demand are also affected by the changes of interest rates (*Δr*) and by the macroeconomic sentiment on the demand side ($\psi_D$) at time t. Coefficients $\varphi_1$, $\varphi_2$ and $\varphi_3$ determine the impact of the selected variables.

The loan supply function is defined in equation (10). The intention of banks is to provide loans while keeping their risk profile at a certain level. The risk of providing a loan is measured in terms of LTV and DSTI. *Ltv* and *dsti* of an agent *i* before and after acquiring new loans ***ΔL*** are calculated as:

$$ltv_i^t = \frac{L_i^t}{W_i^t} \tag{14a}$$

$$ltv_i^{t+1} = \frac{L_i^t + \Delta L_{gross,i}^{t+1}}{W_i^t + \omega * \Delta L_{gross,i}^{t+1}} \tag{14b}$$

$$dsti_i^t = \frac{k_{LC} * LC_i^t + k_{LNF} * LNF_i^t}{YD_i^t} \tag{15a}$$

$$dsti_i^{t+1} = \frac{k_{LC} * LC_i^t + k_{LNF} * LNF_i^t + k_{LC} * \omega * \Delta L_i^{t+1} + k_{LNF} * (1-\omega) * \Delta L_i^{t+1}}{YD_i^t} \tag{15b}$$

Both the regulator and a bank set threshold limits for LTV and DSTI. Regulatory thresholds may be noted $ltv_R$ and $dsti_R$. In case an agent meets both regulatory thresholds, a bank is allowed to provide the whole demanded amount. Otherwise, the bank does not provide the whole demanded amount. The maximum amounts banks are willing to provide in case $ltv_R$ or $dsti_R$ criteria are not met are defined in equation (10). The equation defines the maximum loan amount banks are allowed to provide before the overall amount of loans reaches some percentage of agent's wealth with regard to $ltv_R$; and the maximum loan amount before the overall debt service (repayment including interest payments) reaches a defined percentage of agent's disposable income (with regard to *dsti*). On top of requiring regulatory LTV and DSTI values, banks may apply stricter values than the regulator

– loan supply may be lowered by bank's own risk aversion factor ($\psi_B$) and by the macroeconomic sentiment on the supply side ($\psi_S$). Loan supply is also affected by the changes of interest rates ($\Delta r$).

Equations (12a) and (12b) are rather technical. They ensure the correctness of aggregate amounts of *AF* and *ANF*. That is, if an individual agent takes a mortgage loan of amount $\Delta LNF_{gross}$, her non-financial assets *ANF* increase. However, if this is the case of an already existing real estate property, another agent's *ANF* must decrease and, at the same time, his financial assets *AF* must increase. The consequences of existing real estate property trades could not have been modelled up to this point in the model, therefore, *AF* and *ANF* are adjusted here. The main output of the model is the value of velocity, respectively the changes of velocity, as described in equations (13a) and (13b).

*MPC Scenarios*

The simulation is run under 16 scenarios, which are combinations of a wealth/income distribution and an MPC distribution. The scenarios, therefore, differ in MPC ($\alpha_1$ and $\alpha_2$) distribution and wealth/income distribution. Four different distributions are suggested: a) "Equality"; b) "Lognormal"; c) "Normal" and d) "Uniform". In the case of equality, wealth/income or MPC is the same for each agent. In other cases, wealth/income or MPC follow standard normal, lognormal, or uniform distributions. Equality and uniform distributions were chosen as extreme scenarios. Under equality, all subjects share the same characteristics. Under uniform distribution, the characteristics increase or decrease between certain bounds. According to literature (Clementi, Gallegati and Kaniadakis 2010; Pinkovskiy and Sala-i-Martin 2009), most income distributions tend to be skewed with a peak in the lower-middle income range and have a long right-hand tail. The lognormal distribution, therefore, provides one of the best fits. Although the normal distribution is inferior for describing income distributions, it is kept for comparison due to its notoriety and easy interpretability. All suggested distributions are well-known, easy to interpret, widely used in theoretical models and technically feasible. Their graphical presentation can be found in the Annex.

## Results

The graphical results of the simulation, which was run in R programming language, are presented in Figure 1. The columns differ in wealth/income distribution and the rows differ in MPC distribution. Thus, the graph is divided into sixteen sub-windows, each representing a unique combination of wealth/income distribution and MPC distribution. It is assumed that wealth and income are always distributed in the same manner (e.g., if wealth follows a normal distribution in a scenario, income follows a normal distribution in that particular scenario as well). In addition, $\alpha_1$ and $\alpha_2$ are always distributed in the same manner. The initial values of assets (*AF*, *ANF*), disposable income (*YD*) and liabilities (*L*) in each scenario are also distributed by the corresponding wealth/income distribution of each scenario.

The simulation is run over 96 periods, which may be understood as 8 years times 12 months. The output of the simulation is the velocity of money calculated at the end of each period *t* as the sum of aggregate *YD* over the 12 last periods divided by average liabilities *L* over those last 12 periods.

The initial values of macroeconomic variables at time $t$ = 0 were set as follows: $YD$ = 10mil/12 (therefore, annual $YD$ = 10mil; $AF$ were set to be 3-times and $ANF$ to be 4,5 times annual $YD$; total liabilities $L$ equal to 60% of annual $YD$, from which 20% are $LC$ and 80% $LNF$). The initial values of $AF$, $ANF$ are averages of OECD countries in 2018, which provides the best combination of up-to-date and available data. The initial value of $L$ = 60% is lower than the OECD average. Therefore, it is closer to countries with relatively lower household indebtedness. The ratio of $LC$ to $L$ ($\omega$) varies greatly among OECD countries, reaching values between 4-60%. The variability is large even when comparing only European countries. The suggested value 20% was chosen to be somewhere in the middle of the extremes.

The baseline parameter setting of the simulation was: $\alpha_1 = 0.35$, $\alpha_2 = 0.01$, $k_{LC} = 0.5$, $k_{LNF} = 0.1$, $\omega = 0.2$, $r_{AF} = 0$, $r_{ANF} = 0.02$, $p_{ANF} = 0.03$, $\Delta r = 0$, $\psi_S = 0$, $\psi_B = 0$, $\psi_D = 0$, $\rho = 0.15$, $ltv_R = 0.8$, $dsti_R = 0.5$, $\varphi_1 = 0.1$, $\varphi_2 = 0.004$, $\varphi_3 = 0$, $\varsigma = 0$. The simulation process is intended to capture the increasing indebtedness of agents over time. Therefore, parameters $\alpha_1$, $\alpha_2$ and $\rho$ decrease (by 0.001, 0.00002 and 0.0005) and parameter $\varphi_2$ increases (by 0.00002) over time for each $t$. The value of other parameters remains stable during all simulation periods.[6]

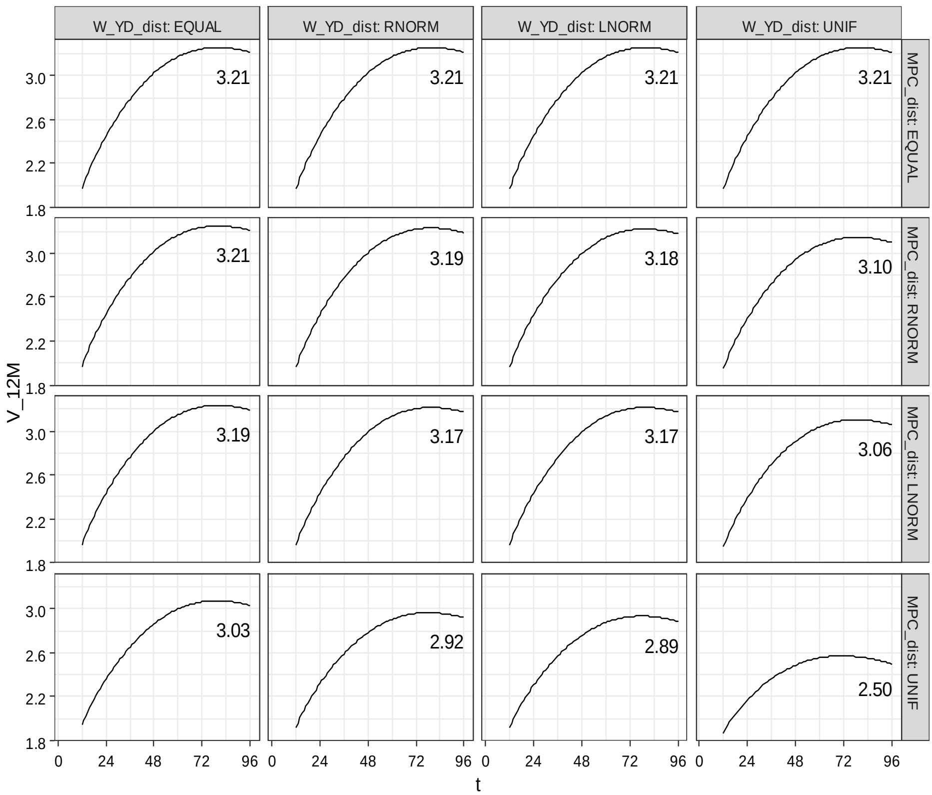
The value of parameter $\alpha_1$ was set within the range of estimates found in Caroll et al. (2017) and Kumhof, Ranciere and Winant (2015). To the best knowledge of the author, the value of parameters $\alpha_2$, $\varphi_1$, $\varphi_2$ and $\varphi_3$ has not yet been quantified in the existing literature. Therefore, their values were set in a way that the simulated values of $YD$, $AF$, $L$ and $C$ do not "explode" over the simulation period, but evolve rather gradually, like macroeconomic values of real economies. Zero values of $\psi_S$, $\psi_R$ and $\psi_D$ are replaced by non-zero values in scenarios concerning LD and LS shocks. The repayment ratios were set so that consumer loans are repaid over 2 years; and mortgage loans are repaid over 10 years. The macroprudential values of $ltv_R = 0.8$ and $dsti_R = 0.5$ are standard values used by regulatory authorities (Lang et al. 2020). The changes of interest rates are assumed to be zero for the sake of simplicity (as the main focus of the model is not put on interest rates). The assumption that financial assets AF yield zero interest is not far from reality in the environment of very low interest rates. For example, according to euro area statistics, the average bank deposit rate with an agreed maturity of less than one year was 0.2% in 2020, of which many countries' deposit rate was practically at zero level. Non-financial assets yield a positive return and positive capital gains.

The shape of the velocity curve reflects a growing economy where aggregate demand rises more than debt. The later stage of the observation period is, however, characterized by debt rising more than YD. Comparing the wealth/income distributions, velocity reaches highest levels when wealth/income are distributed equally. On the other hand, a uniform distribution, the most unequal distribution out of the suggested ones, causes velocity to reach the lowest values. Looking at the graph from left to right, it is apparent that wealth/income inequality results in lower velocity. A more equal distribution results also in a faster rise of velocity; and in a slower decline in later periods, which is in line with Bahadir, De and Lastrapes (2020) who reveal that the long-run change of spending

[6] Sensitivity analysis of parameter setting could have been conducted but was abandoned due to the large number of variables, as the results would inflate the length of the paper extensively.

tends to be larger for countries with a more unequal distribution of income. The results are also in line with Palley (1997) as the changes in the distribution of wealth/income may cause changes to aggregate income and velocity directly, even without the changes in MPC or other factors. The only exception to this pattern is the first row – MPC equality – where velocity is not affected by the wealth/income distribution at all. Looking at the graph from top to bottom, similar logic applies for the MPC distribution – velocity reaches the highest levels when MPC is distributed equally and the lowest levels under the uniform distribution.

**Figure 1. Simulation results showing the development of *V* and its final value at *T***




Maximum velocity occurs when all agents consume the same part of their income and wealth (first row) – the society where everyone consumes the same proportion of his wealth/income manages to operate with relatively less liabilities with regard to its income (or with relatively higher income with regard to its liabilities).

Normal and lognormal MPC distributions differ in several ways. However, out of the four distributions investigated in the simulation, these two provide the most similar results. The final velocity is slightly higher when MPCs are distributed normally rather than lognormally. This is because under a normal distribution, wealth and income are distributed slightly more equally.

The minimum velocity occurs if both wealth/income and MPC share a uniform distribution (bottom-right corner). In this case, there is the most distinctive disproportion between wealth/income and MPC – the poorest agents consume the most of their wealth/income while the richest ones consume the least. The system is not very "fair" – those who contribute to the creation of new income relatively the most are the ones who benefit the least from it (because the share of income they receive each period is relatively small). However, it is interesting that even in a society with extreme wealth/income inequality (where the top decile holds approximately 19% of wealth while the bottom decile holds only 1% at the beginning of the simulation), which is the case of a uniform wealth/income distribution, velocity can record high values if MPC is distributed equally (top-right corner).

*Shocks*

The set of shocks was applied to each scenario.[7] The shocks are applied to: a) loan demand, stressing the parameter $\psi_D$; b) loan supply, stressing the parameter $\psi_S$ (respectively $\psi_B$); c) regulatory ratios LTV and DSTI ($ltv_R$ and $dsti_R$); d) repayment ratios ($k_{LC}$ and $k_{LNF}$); e) real estate price changes $p_{ANF}$; f) change in the structure of loan demand – i.e., change of the ratio $\omega$; g) the marginal propensity to consume ($\alpha_1$ only); and h) the ratio of new RE property transactions to all RE property transactions ($\rho$). The shocks are defined as a 10 % increase of given parameters at time $t$ = 2 and 73; and a 10 % decrease at $t$ = 37. The shocks continue to exist in the following periods, but at a decreasing rate (the decay rate of shocks is 0.9). The above-listed shocks are applied independently to each other (the shocks are never combined). The graphical comparison of the shocks is presented in Figures 2a and 2b. The velocity of money is calculated at the end of each period $t$ as the sum of aggregate income over period $t$ is divided by liabilities $L$ at the end of that period. The graph presents the difference between the value of velocity after a shock is applied minus the velocity resulting from the baseline parameter setting.

Shocks were divided into two charts because the impact of shocks (a) to (f) is apparently of lower magnitude than the impact of shocks g) and h). Few notes may be made about the impact of the shocks. The LD (a) and LS (b) shocks result in a very similar way. They even overlap when MPC is distributed equally. However, when both wealth/income and MPC follow a uniform distribution, the lines diverge quite a lot. This is because when wealth/income and MPC follow a uniform distribution, relatively more agents are unable to fulfill LTV and DSTI requirements set by banks and LD exceeds LS. The LD and LS shocks mostly cause velocity to rise, but in some scenarios, velocity falls after positive LD or LS shock; the fall being bigger in late periods of simulation, when the indebtedness of agents is relatively higher.

Out of all shocks, the shock to the regulatory ratios (c) is of the lowest magnitude. When MPC is distributed equally, the change of regulatory ratios has absolutely no impact on velocity. In other scenarios, the impact on velocity may be positive and negative, but the impact is very limited. It applies to both shocks (d) and (e) that, in general, positive shocks to repayment ratios and to RE capital gains cause velocity to rise; and negative shocks cause velocity to decline. However, there is a difference between the two when observing

[7] To avoid any doubts – a scenario means a unique combination of wealth/income distribution and MPC distribution. There are 16 scenarios in total. Shocks mean stressing a certain simulation variable at specific periods. Shocks are applied to each scenario independently.

differences among scenarios. Positive repayment shock causes velocity to increase the most under wealth/income and MPC inequality. Positive capital gains shock, on the other hand, has the lowest effect on velocity under MPC wealth/income and MPC inequality. Interestingly, velocity reaction to the positive capital gains shock is the strongest under the combination of uniform MPC with equal wealth/income.

Shock (f) entails the change of the proportion of consumer loans to mortgage loans. The increase of *LC* proportion leads to immediate velocity increases followed by longer-lasting decreases. This means that when agents demand relatively more *LC*, *YD* increases faster than agents' liabilities at first, but as time goes by, *YD* starts to increase slower than *L*. On the other hand, decreases of *LC* proportion lead to immediate velocity decreases followed by longer-lasting increases. Velocity rises the most (or decreases the least) when MPCs is distributed unequally.

Shock (g) demonstrates that increases (decreases) of $\alpha_1$ increase (decrease) the final velocity. Higher $\alpha_1$ translates into greater consumption, which in turn translates into income growth that outweighs the increase in loans. Together with the shock to the proportion of RE property purchases (f), these shocks have by far the greatest impact on the velocity. Both variables cause velocity to rise if there is a positive shock and vice versa.

This analysis proves that all shocks – respectively variables they represent them – influence the dynamic relationship between loans provided and aggregate income. This is a major modelling extension of the "debt-income problem". For example, the model of Xiong, Fu and Wang (2017) included the MPC variable and focused also on the repayment process. This paper analyzes eight different shocks containing ten variables, plus each of these shocks is examined in 16 different states of wealth/income and MPC distributions.

**Figure 2a. Simulation results showing the impact of shocks on velocity – shocks (a) to (f)**

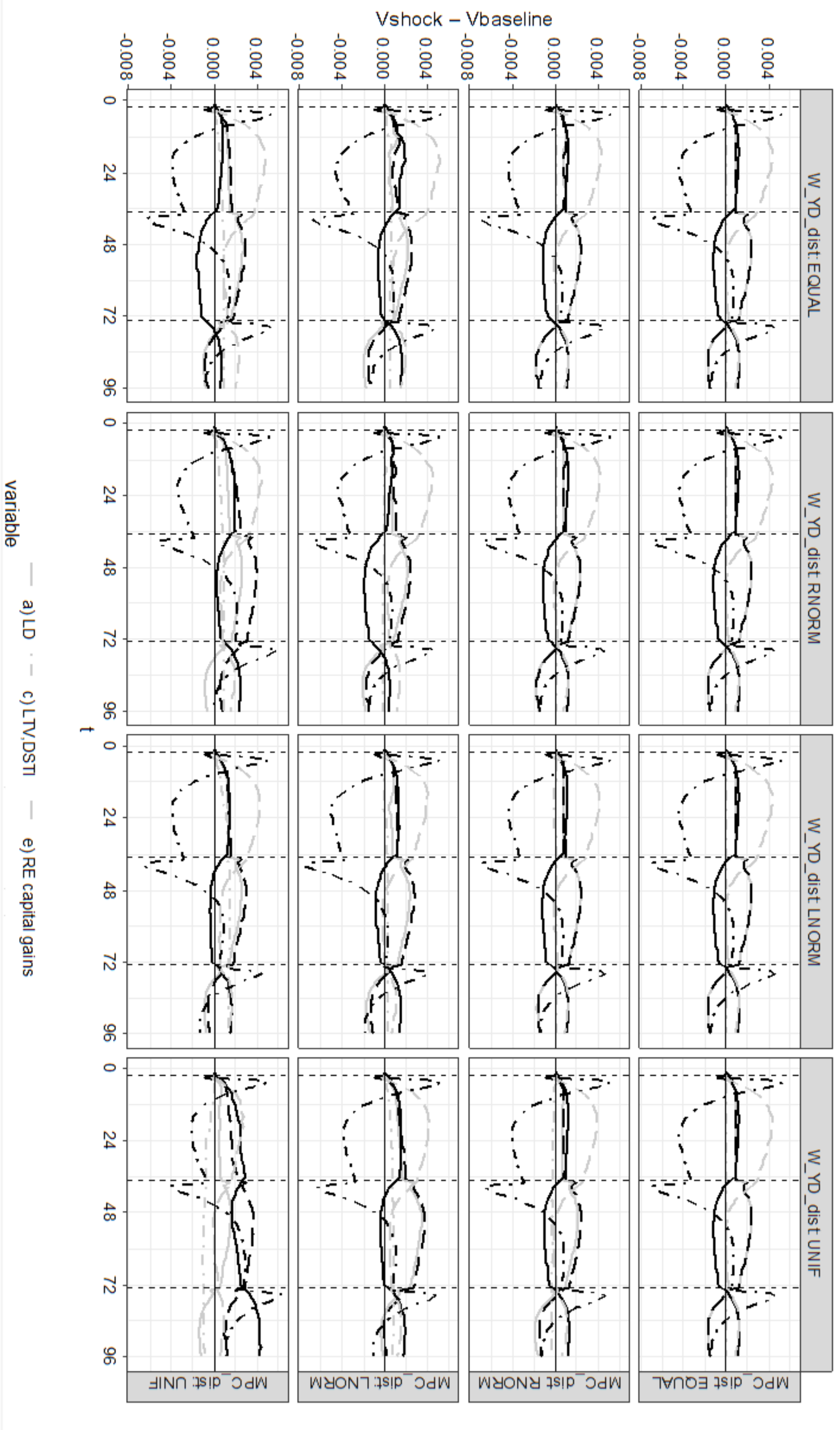
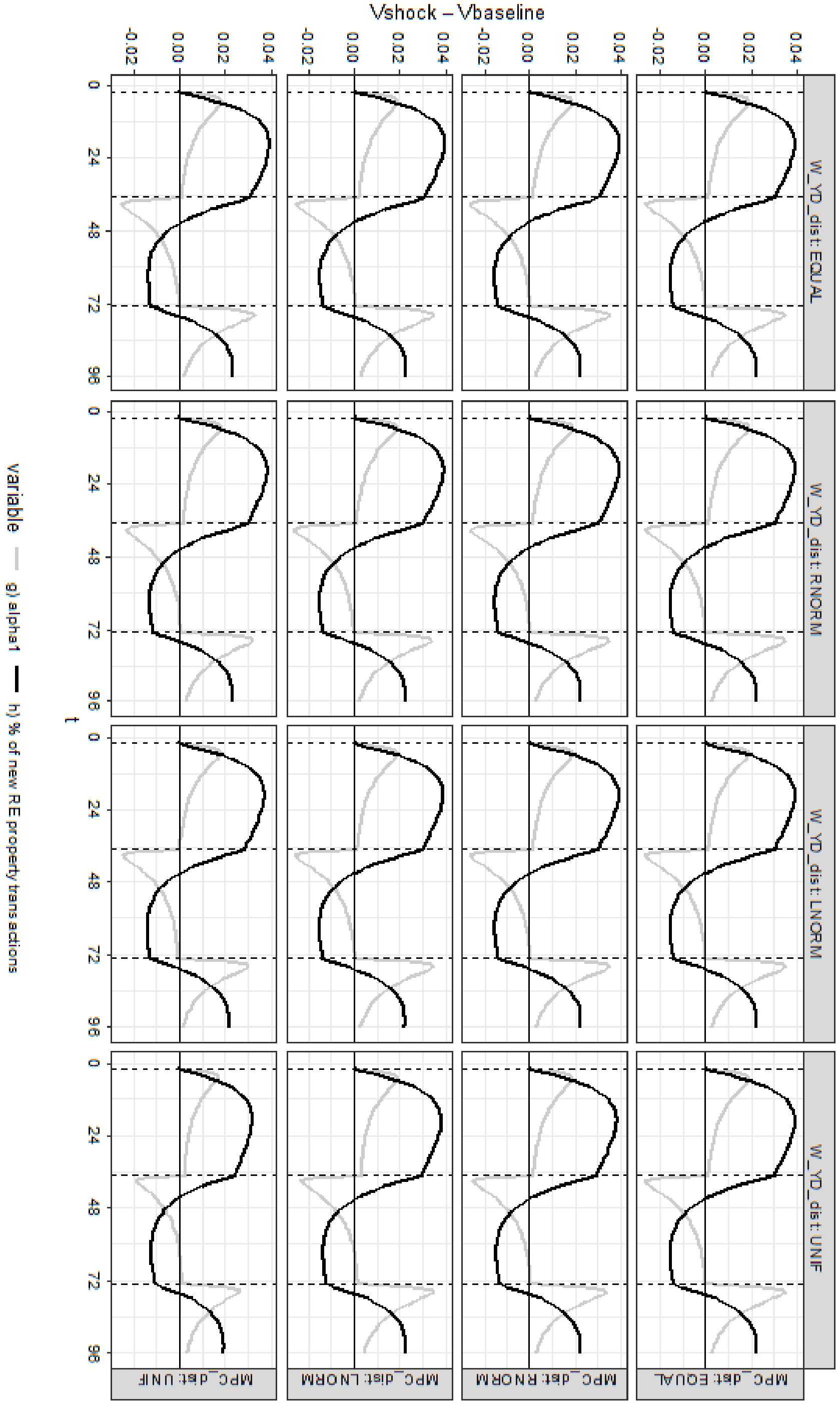


**Figure 2b. Simulation results showing the impact of shocks on velocity – shocks (g) and (h) (different scale)**



## Conclusion

An original agent-based simulation model was constructed to examine the impact of various financial shocks on the income velocity of money under different distributions of wealth/income and MPC. The model involves consumption and wealth accumulation process, loan demand, supply and repayment function, and is complemented with the existence of macroprudential restrictions. The investigation has shown that velocity reaches the highest levels when 1) MPC is distributed equally among households and 2) wealth/income is distributed equally. Velocity decreases with increasing inequality of wealth/income and MPC. Velocity can reach high values even in an economy with extreme wealth/income inequality on the condition that MPC is distributed equally. These findings fill the missing gap in the literature on velocity, wealth/income distribution and MPC distribution. A society with equally distributed wealth/income and MPC is able to reach the same levels of aggregate income with less indebtedness, compared to a society with more unequal distributions.

A set of eight different macroeconomic shocks was used in the model to capture the complexities of real-world issues and their impact on velocity – shocks to loan demand, loan supply, MPC, macro-prudential regulatory ratios, real estate capital gains, repayment ratios, to the structure of loans provided and to the structure of real estate property transactions. The MPC shock and the shock to the structure of RE property purchases have the largest impact on velocity. A positive MPC shock causes velocity to rise remarkably. Similarly, if more newly built RE properties are sold (relative to already existing RE properties), velocity rises. The pattern of these shocks is the same across all scenarios, but their magnitude decreases with increasing inequality. The shock to regulatory ratios has the lowest magnitude – its impact is practically zero, except for the scenarios with a uniform MPC distribution where some agents are willing to consume more than they can afford, but are not provided additional loans due to macroprudential constraints.

The increase of the ratio of consumer to mortgage loans increases velocity temporarily, but at the cost of subsequent reduction. The increase of the ratio of consumer loans to mortgage loans increases velocity the most when MPC is distributed unequally. The same pattern occurs with the repayment ratios shock – when repayment ratios increase, velocity increases the most if MPCs and wealth/income are distributed unequally. A positive capital gains shock, on the other hand, has the lowest effect on velocity under the combination of MPC and wealth/income inequality. The capital gains shock affects velocity the strongest under the combination of a uniform MPC distribution with wealth/income equality.

The shocks to loan demand and to loan supply affect velocity very similarly in most cases. However, when both wealth/income and MPC follow a uniform distribution, the impact of LD and LS shocks diverges remarkably as relatively more agents are unable to fulfill LTV and DSTI requirements when wealth/income and MPC are distributed unequally, and LD exceeds LS. The impact of LD and LS shocks generally causes velocity to rise when the indebtedness of agents is relatively low and vice versa.

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## Annex – distributions

**Figure 3. Financial assets distribution (360 million of currency (CCY) distributed to 1000 agents). Max values in CCY: a) 360 000, b) 724 000, c) 482 000, d) 855 000. Top decile %: a) 10%, b) 19%, c) 12%, d) 14%.**

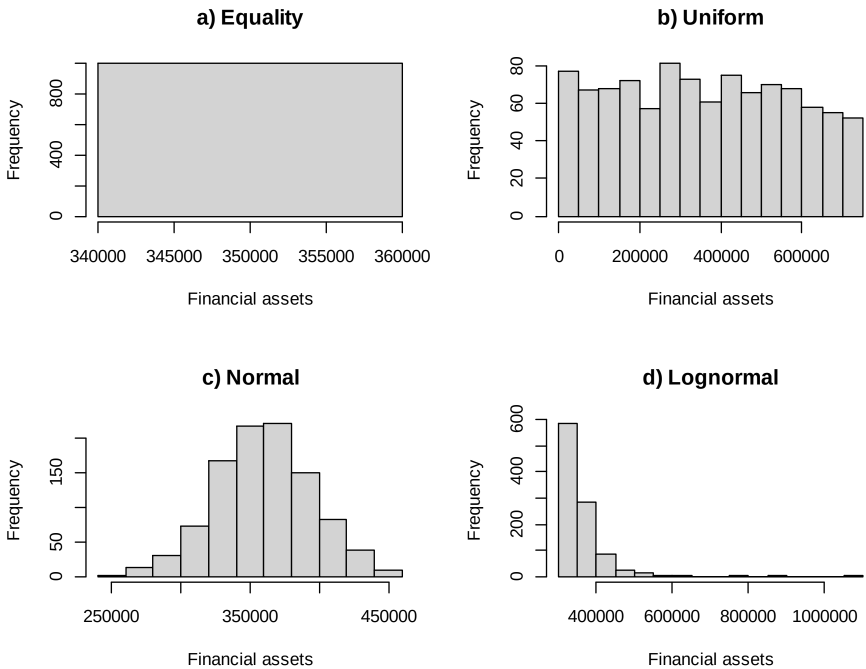

**Figure 4. MPC distribution (mean = 0,5); max values: a) 0.5 being also minimum, b) 0,99, c) 0,66, d) 1.**