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TANK, helicopter, and how to use new weapons to reach old targets

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JEL Codes: E41, E42, E51, E52, E58

Keywords: helicopter money; quantitative easing; heterogenous agents



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Supervised by Gilles Saint-Paul

with the help of Tobias Broer
and Axelle Ferriere



PARIS SCHOOL OF ECONOMICS
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TANK, helicopter, and how to use new weapons to reach old targets

Yann Perdereau *

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Abstract

What have been the effects of quantitative easing in Europe since 2008, and would helicopter money have been a better way to allocate the new money created? Since only a fraction of households holds assets, and since their marginal propensity to consume is quite low, the assets purchase program by the European Central Bank may be less efficient than a direct transfer of money to all households, *i.e.* helicopter money. Using a Two-Agent New-Keynesian (TANK) model, we simulate the QE program in Europe between 2009 and 2019, and find that this policy had sizable effects on inflation, consumption and output, but that helicopter money would have been more efficient, while reducing inequalities during this period.

Keywords: helicopter money; quantitative easing; heterogenous agents.

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”Using unrealistic examples is often a useful way at getting at the essence of an issue. The fact that no responsible government would ever literally drop money from the sky should not prevent us from exploring the logic of Friedman’s thought experiment.” Bernanke (2016)

1 Introduction

Can we deal with unconventional times using conventional tools? Since 2008 and the financial crisis, governments and central banks have been facing increasingly complex dilemmas, with the need to stabilize the economy with increasingly reduced room for maneuver. The interest rate, which is the main tool of central banks, has reached the zero lower bound in most advanced economies, and the public debt, which reflects the fiscal space of government, has reached an all-time high ; in the same time, the need for accommodative policies has become the norm with the recover from the subprime crisis, the sovereign debt crisis and the Covid-19 pandemic. This weakening of standard tools led the central banks to use unconventional monetary policies, with the launch in 2009 in Europe of a massive assets purchase program, *i.e.* quantitative easing. This money injection to buy mainly government bonds, aiming at developing economic activity, raising inflation and lowering interest rate, started between 2009 and 2011 with the Securities Markets Programme (SMP) of the European Central Bank, before being considerably expanded in 2015 by Mario Draghi and the ECB’s Asset Purchase Programme (APP). Originally planned to last until September 2016, this program has constantly been renewed and augmented, until 2020 and the Pandemic Emergency Purchase Programme (PEPP) to help the economy absorb the shock of the Covid-19 crisis. As a result, the balance sheet of the Eurosystem jumped from 2.1 trillion in 2008 (including 271 billion of euro area residents securities) to 7 billions in 2020 (including 3.9 trillion of euro area residents securities).

If this massive asset purchase program has undoubtedly contributed to growth and inflation since 2008 (we will discuss later the empirical and theoretical evidence), it also has been criticized regarding two aspects: the mode of injection

of the new money and the recipients. Indeed, by purchasing financial assets, the QE may have contributed to increase financial activity rather than real one and, by focusing on financial assets owners, it may have increased inequalities. Since the efficiency of QE lies in the difference on marginal propensity to consume (MPC) out of liquid and illiquid wealth, and since the MPC of financial assets owners may be much smaller than the average MPC, the quantitative easing may have increased inequalities without reaching its full potential on the revival of real activity. In its Annual Report 2016, the ECB explains that “households that hold financial assets, such as stocks and bonds, are strongly concentrated at the top end of the net wealth distribution. As such, only a fairly small subset of the population benefits from capital gains in equity and bond markets; three-quarters of the population do not benefit at all.” Then, the report computes that the wealth effect induced by QE has increased the net wealth of the richest 20 percent by roughly 30 percent, against less than 5% for the bottom 40%, even if the general equilibrium effects, such as the lower unemployment, may have benefited to the poorest.

If the positive effects of the quantitative easing (increase in activity and in inflation, decrease in unemployment and interest rate) come from the very fact of creating money, but if the negative effects (increase in inequality, small efficiency) come from the recipients and the distribution mode, can we imagine a way to create money without purchasing financial assets? What could be the effect of creating money and distributing it directly to people, without buying something in exchange? In other words, can we launch the helicopter? In 1968, Friedman wrote “let us suppose now that one day a helicopter flies over this community and drops an additional \$1,000 in bills from the sky”. Even if Friedman was not a fervent defender of heterodox monetary policies, this parable remained and the term “helicopter money” is now used to describe the irredeemable money creation from the central bank, distributed directly to people or with the intermediary of the government with “money-financed fiscal stimulus”. Then, helicopter money is characterized by the fact that it does not allow the central bank to acquire real assets in return, but also by its recipients: all people are concerned, including people with high marginal propensity to consume, which may induce higher multiplier.

The objective of this paper is to compare the efficiency of quantitative easing and helicopter money in a Two-Agent New Keynesian framework. The New Keynesian model is especially useful for evaluating the effect of monetary policy, as it allows nominal rigidities that result in the non-neutrality of money, as opposed to the classical model. In this paper, the supply side is standard: firms are subject to quadratic price adjustment costs following Rotemberg (1982), and the monopolistic competition yields profits and dividends. However, we differ from the representative agent model by introducing two types of consumer in the demand side: a “Ricardian” one, who receives dividends and has access to financial markets, and a “Keynesian” one, who is more impatient, does not own firms and cannot borrow. This heterogeneity, even in this simplest form, is absolutely crucial to analyze the fiscal and monetary multipliers. If we admit that quantitative easing may go to a fraction of the population that have a lower MPC than the average, it is crucial to introduce different agents, with different marginal propensities to consume. The government collects taxes to finance public spending ; the interesting part of the model lies mainly in the monetary authority, which creates money according to a rule and can either use it to purchase government debt (quantitative easing) or transfer it directly to households (helicopter money). Parameters are calibrated using European data, and the model is simulated to evaluate the effect of QE and helicopter.

If the monetary base increases by a value of 1% of GDP, the results are the following: aggregate variables behave similarly with QE and helicopter, with an increase in consumption of respectively 0.21% for QE and 0.26% for helicopter on impact, and an increase in inflation of respectively 0.10% and 0.14%. Helicopter performs slightly better than QE due to the higher MPC of Keynesian households. Both policies reduce consumption inequalities by increasing wealth, employment and wage, and reducing dividends: however, this decrease in inequality is much more important in helicopter than in QE, because quantitative easing is biased towards Ricardian agents that own public debt, whereas helicopter money distributes equally the new money created to all households. These results are robust to main parameters, and the effects increase with a higher level of nominal

rigidity, a higher monetary shock persistence, and a smaller weight of money in the utility function. The model is then simulated with the actual asset purchase programs undertaken by the European Central Bank to assess the efficiency of QE in Europe since 2008. We find that QE has contributed to increase the GDP by 0.8% each year on average between 2016 and 2019, when the QE program was at its highest level; it also contributed to increase inflation and consumption by respectively 0.6% and 1% on average in the same period. However, the QE program increased the consumption heterogeneity between both types of households (our very stylized measure for inequality) by 1%. This simulation is then re-computed but with helicopter instead of QE: we find that helicopter would have been more efficient, with an average increase of 1.2% in GDP, 0.8% in inflation and 1.6% in consumption each year between 2016 and 2019, which is more than the actual QE, and it would have reduced inequalities by 6% instead of increasing it. We also analyze welfare, and find that the quantitative easing is welfare enhancing mostly for Ricardian agents, whereas the helicopter money is welfare-enhancing for Keynesian agents. However, since the loss of welfare and consumption for Ricardian is much smaller than the gain for Keynesian, the aggregated effect of helicopter money on welfare is positive. Finally, we compute the optimal monetary policy to stabilize business cycle facing productivity shock, and find that since inflation and output are positively correlated following money creation, we cannot achieve a high level of stabilization.

1.1 Related literature

Our paper is related to two literatures that we now review. The first sub-literature is about **unconventional monetary policies**, either effective like quantitative easing, or hypothetical like helicopter money and money-financed fiscal stimulus. Regarding this topic, our paper is especially close from the seminal paper by Gali (2014) on money-financed fiscal stimulus. In this paper, Gali investigates the effects of a fiscal stimulus, either a tax cut or an increase in public expenditures, financed through money creation, and compared it with a debt-financed fiscal stimulus. While the latter is found to have almost no effect on real activity through

Ricardian equivalence (since the additional public debt to finance the stimulus has to be repaid someday, agents anticipate the future rise in taxes and increase their saving instead of their consumption), a money-financed fiscal stimulus can have a large multiplier effect, especially under a liquidity trap.

Our paper builds on Gali's model but differs from it by the use of the money created: instead of using new money to finance fiscal stimulus, we use it to purchase public debt (quantitative easing) or to make a transfer directly to all households (helicopter money). This difference is important: while Gali deals with a policy that differs fundamentally from the QE and then cannot be compared to it, the implementation of helicopter money is related to QE and represents an alternative to it, as it is sometimes called "QE for people". Note, however, that our paper also displays in annex the results from a money-financed fiscal stimulus in our framework, which are close from Gali. The helicopter money has gained attention following the multiple crises of the last decades, and the number of papers dealing with it has increased a lot, as documented in Masciandaro (2020). Among the supporters of this policy, one can note the contribution of Buiter (2014), who uses an overlapping generations model to assess the efficiency of this policy in almost every situation, depending on some conditions that are usually fulfilled. Turner (2013, 2015) also considers that "the prohibition of money financed deficits has gained within our political economy the status of a taboo", and that helicopter could be more effective in stabilizing the economy than the policies currently in use, while avoiding the creation of financial instability and bubbles. Even if this policy has not been implemented anywhere, central banks are now less reluctant to discuss it, with for example Bernanke (2016) considering that "using unrealistic examples is often a useful way at getting at the essence of an issue. The fact that no responsible government would ever literally drop money from the sky should not prevent us from exploring the logic of Friedman's thought experiment", or Draghi (2016) estimating that "[helicopter money] is a very interesting concept that is now being discussed by academic economists". Of course, some economists totally disagree with this hypothetical policy, and consider that it could lead to hyperinflation, loss of credibility or independence for central banks, or re-

quires giving up on interest rate policy forever, as in Borio, Disyatat and Zabai (2016). While these concerns are of first importance, our paper considers that the legal obstacles and the potential risks should not prevent thinking about these unconventional policies, or improving the quantitative easing program. Moreover, as we estimate in our paper, the increase in inflation following helicopter money is quite small, and may even be seen as a gain in a time when central banks are struggling to meet their inflation target.

This paper is about helicopter money, but also about quantitative easing, since the very idea behind it is that QE may not be the most efficient way to allocate the money created. By replacing illiquid assets by liquid wealth, the QE targets people with low MPC, which may reduce its efficiency compared to helicopter money, and increase inequalities. Saiki and Frost (2014) use empirical evidence from the assets purchase program in Japan to show that it widened income inequality, due to the portfolio channel : “the increase in asset prices [...] disproportionately benefits those households with greater financial assets holdings, which typically have high income.” Our paper is more theoretical than theirs, and considers only a toy version of inequalities, relying heavily in our QE analysis on the work of Cui and Sterk (2019), who found that QE is an efficient tool to anchor expectations and stabilize business cycle, but at the price of more inequality and a lower welfare. As their paper, we try to estimate the effect of QE since 2008, but we depart from their framework by introducing a different version of household heterogeneity and by considering another form of money injection, *i.e.* helicopter money.

The second sub-literature is about **heterogeneous agents in NK models**. The representative agent model, by essence, does not allow to deal with inequality, but more importantly, by imposing the same marginal propensity to consume to all agents, it excludes some crucial transmission channels of monetary policy. For example, if all agents receive equally dividends and own equally financial assets, QE and helicopter may be completely identical. However, if some agents are constrained, have a lower MPC or do not receive dividends, the efficiency of QE and helicopter may differ. This is why we consider that heterogeneity is crucial to deal with monetary policy, and we use a Two-Agent New-

Keynesian framework (TANK). As shown by Debortoli and Gali (2015), this very reduced form of heterogeneity captures reasonably well the results from a more sophisticated Heterogeneous-Agent NK model (HANK), while being much more tractable. This TANK framework is also used by Bilbiie and Ragot (2016), who consider that households participate infrequently in financial markets: they insure against this loss of access to financial markets by holding money. In this framework, authors compute the optimal monetary policy and derive a trade-off between stabilizing business cycles and inequalities. In the same idea, Cui and Sterk (2019) propose a model where agents hold money to insure against the loss of their job: heterogeneity comes from the employment status. Our model does not consider transition between types over time, and formulates its heterogeneity considering that one type of agent, called “Keynesian households”, is credit-constrained: they cannot borrow from financial markets. Moreover, they do not receive dividends from firms, and they are more impatient. This framework allows to introduce different marginal propensities to consume across people, which is key to analyze the difference between QE and helicopter. In this regard, our paper is close to the paper by Punzo and Rossi (2016) which extends the money-financed fiscal stimulus proposed by Gali (2014) to a TANK framework and similarly finds that it is more expansionary than a debt-financed one. As mentioned above, we consider the same credit-constraint specification, but we use this framework to analyze different types of monetary policies, *i.e.* QE and helicopter money. Finally, our model draws significant inspiration from the two-agent model of Bilbiie, Monacelli and Perotti (2013), which considers fiscal policies in this framework.

1.2 A simple formula

Before we start to present the model, we reproduce and discuss the simple formula presented by Cui and Sterk (2019) to compute the effects of QE on aggregate demand, and we apply it to helicopter money to get a first insight of the objective of this paper. Cui and Sterk postulate that the aggregate consumption C is a function of three variables: liquid assets L like money or deposits, illiquid assets I like government bonds or financial assets, and a third variable Γ containing other

relevant aspects such as wages and prices. Then the aggregate demand function writes $C(L, I, \Gamma)$. Authors assume a shock of quantitative easing with a value Δ^{QE} : the central bank purchases illiquid assets I and replaces them by liquid wealth L , so that the new demand function is equal to $C(L + \Delta^{QE}, I - \Delta^{QE}, \Gamma(\Delta^{QE}))$. If we differentiate this function with respect to Δ^{QE} to get the marginal effect of QE on aggregate demand, we get:

$$\frac{\partial C}{\partial \Delta^{QE}} = \underbrace{MPC^L - MPC^I}_{\text{direct effect}} + \underbrace{GE}_{\text{indirect effect}}$$

where $GE = C_{\Gamma}(L, I, \Gamma) \frac{\partial \Gamma}{\partial \Delta^{QE}}$ and where MPC^L and MPC^I denote the marginal propensities to consume out of liquid and illiquid wealth. Then the effect of QE depends on the direct effect of the money injection, which is the difference in the marginal propensities to consume out of the two types of wealth, and the indirect effect, which is the general equilibrium effect of QE. Taking $MPC^L = 0.63$ and $MPC^I = 0.095$, and considering that “checkable deposits held by households increased from about 1.5 to 6.3 percent of annual GDP” between 2007 and 2017 in the US, Cui and Sterk are able to provide a simple estimation of the direct effect of QE, equal to $(6.3 - 1.5)(0.63 - 0.095) = \mathbf{2.57 \text{ percent of GDP}}$, which is quite substantial.

This simple formula conveys important insight on the efficiency of quantitative easing to stimulate aggregate demand. However, the implicit assumption is that the quantitative easing gives liquid wealth equally to all households, so that we can simply take the average MPC out of liquid wealth between all individuals. In reality, we might think that people holding financial illiquid wealth have a lower MPC than the average. Carroll et al. (2017) estimate that the MPC out of liquid wealth is about 0.25 for the top 50% wealth, and about 0.76 for the bottom 50%, with an overall average MPC of 0.51, so that if QE mostly goes to the wealthiest, the effect on consumption will be smaller than the effect computed by Cui and Sterk. To be fair in our comparison, let’s recompute the QE effect in US using the Carroll et al. MPC equal to 0.51 instead of 0.63 as in Cui and Sterk: we get a direct effect of $(6.3 - 1.5)(0.51 - 0.095) = \mathbf{1.99 \text{ percent of GDP}}$. Now, let’s consider that only the top 50% holds financial illiquid assets, so that the QE only goes to

the top 50% (with a MPC equal to 0.25 instead of 0.51), and let's call these 50% the "Ricardian", indexed by R. Now the marginal effect of QE is

$$\frac{\partial C}{\partial \Delta^{QE}} = MPC_R^L - MPC_R^I + GE$$

If we compute again the direct effect but using the MPC of the wealthiest 50% instead of the average MPC, we get that the QE has a direct effect of $(6.3 - 1.5)(0.25 - 0.095) = \mathbf{0.74 \text{ percent of GDP}}$, which is much smaller than the 1.99 percent that we found using average MPC.

Finally, let's imagine that instead of running an assets purchase program, the central bank decides to transfer money Δ^{HM} directly to all people, without buying something in exchange. In this "helicopter money" scenario denoted HM, the aggregate consumption is $C(L + \Delta^{HM}, I, \Gamma(\Delta^{HM}))$ and the marginal effect would be

$$\frac{\partial C}{\partial \Delta^{HM}} = MPC^L + GE$$

where $GE = C_\Gamma(L, I, \Gamma) \frac{\partial \Gamma}{\partial \Delta^{HM}}$. Since new money is transferred to every households, we can use the average MPC and compute the direct effect of helicopter money in the US between 2007 and 2017, which would have been $(6.3 - 1.5)(0.51) = \mathbf{2.45 \text{ percent of GDP}}$, much higher than the 0.74 we found for QE. This simple formula is of course very stylized, because it considers that only the wealthiest people hold assets and abstracts from general equilibrium effects, but it may be useful to understand the effect of quantitative easing, the importance of marginal propensity to consume and the difference between QE and helicopter money in our model.

The remainder of the paper is organized as follows. Section 2 describes formally the non-policy blocks of the model and the monetary framework used in the analysis. Section 3 compares helicopter money and quantitative easing, and tests the results for different specifications of the model and the parameters. Section 4 estimates the efficiency of the quantitative easing program in Europe since 2008, as well as the potential effect of helicopter money in the same period. Section 5 analyses the welfare effects of both monetary policies, and section 6 computes

the optimal monetary policy to stabilize inflation and output facing productivity shocks. Section 7 summarizes the main findings and concludes.

2 The model

This section presents a general equilibrium model that allows to compare the effect of quantitative easing and helicopter money, as we have defined them. The model economy is populated by households, firms, a government and a central bank; the key features of the model are that nominal prices are sticky to allow the non-neutrality of money, that there are two types of households with different marginal propensities to consume, that the central bank can create money and purchase assets to households, and that households hold money and government debt.

2.1 Households

There is a continuum of infinitely-lived households indexed by their type i who have preferences defined over private consumption $C_{i,t}$, real balances $\frac{M_{i,t}}{P_t}$, and labor services $N_{i,t}$, according to the following utility function:

$$U_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t \left[(1 - \chi) \ln C_{i,t} + \chi \ln \frac{M_{i,t}}{P_t} - \psi \frac{N_{i,t}^{1+\varphi}}{1+\varphi} \right] \quad (1)$$

The operator \mathbb{E}_t is the expectations operator conditional on information available in period t , β_i is the subjective discount factor for type i , φ is the inverse of the labour supply elasticity, χ measures the weight of real balances relatively to private consumption, and $C_{i,t}$ is a CES aggregator of the quantity consumed $C_{i,t}(z)$ of any of the infinitely many varieties $z \in [0, 1]$ and it is defined as:

$$C_{i,t} = \left[\int_0^1 C_{i,t}(z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

2.1.1 Ricardian

A $1 - \lambda$ share is represented by households who are patient, have access to financial market, receive dividends D_t and own a part B_t^H of the government debt B_t : we label them "Ricardian", and they are indexed by R . They have access to four different assets: money $M_{R,t}$, one-period nominally riskless bonds $A_{R,t}$, one-period government debt and shareholdings. In each period t , they choose their consumption, hours worked, money and asset holdings subject to the nominal budget constraint

$$P_t C_{R,t} + A_{R,t} + B_{R,t}^H + M_{R,t} \leq (1 + i_{t-1})(A_{R,t-1} + B_{R,t-1}^H) + q P_t D_t + M_{R,t-1} + W_t N_{R,t} (1 - \tau_t) + P_t T_t \quad (2)$$

At each period, the Ricardian household receives the interest i_t on the real value of its previous financial assets $A_{R,t-1} + B_{R,t-1}^H$, a share q of the real dividends, the after-tax nominal wage $(1 - \tau_t)W_t$ per hour worked and a real transfer T_t from the central bank. Note that, since only Ricardian households own the firms, we have $(1 - \lambda)qD_t = D_t$ so that the share is equal to $q = \frac{1}{1-\lambda}$. The no-Ponzi game condition is assumed to hold at all dates. Given prices, policies and transfers $\{P_t, i_t, D_t, W_t, T_t\}$, the Ricardian households choose the set of processes $\{C_{R,t}, N_{R,t}, M_{R,t}, A_{R,t}, B_{R,t}^H\}$ to maximize (1) with respect to (2), which yields the following first-order conditions:

$$\beta_R \mathbb{E}_t \left[\frac{C_{R,t}}{C_{R,t+1}} \frac{1 + i_t}{\pi_{t+1}} \right] = 1 \quad (3)$$

$$\frac{\psi_R N_{R,t}^\phi C_{R,t}}{1 - \chi} = w_t (1 - \tau_t) \quad (4)$$

$$\frac{M_{R,t}}{P_t} = \left(\frac{\chi}{1 - \chi} \right) C_{R,t} \left(1 + \frac{1}{i_t} \right) \quad (5)$$

where inflation is denoted $\pi_t = \frac{P_t}{P_{t-1}}$ and real wage is denoted $w_t = \frac{W_t}{P_t}$. Note that this notation for inflation implies that a no-inflation state means $\pi = 1$ and not $\pi = 0$. The inter-temporal equation (3) is called the Ricardian Euler equation, the

equation (4) is the Ricardian labor supply, and the equation (5) is the Ricardian money demand.

2.1.2 Keynesian

A λ share is represented by households who are impatient, credit constrained, and do not own firms or government debt: we label them "Keynesian", and they are indexed by R . They have access to two different assets: money $M_{K,t}$ and one-period nominally riskless bonds $A_{K,t}$, but they cannot borrow at the equilibrium. In each period t , they choose their consumption, hours worked, money and asset holdings subject to the nominal budget constraint

$$P_t C_{K,t} + A_{R,t} + M_{K,t} \leq (1 + i_{t-1})A_{K,t-1} + M_{K,t-1} + W_t N_{K,t} (1 - \tau_t) + P_t T_t \quad (6)$$

At each period, the Keynesian household receives the interest i_t on the real value of its previous financial assets $A_{K,t-1}$ (which is zero due to the credit constraint below), the after-tax nominal wage $(1 - \tau_t)W_t$ per hour worked and a real transfer T_t from the central bank. Moreover, we assume that Keynesian households are credit-constrained at all times t :

$$A_{K,t} \geq 0 \quad (7)$$

The Lagrange multiplier associated to this constraint is ϕ_t : whenever this multiplier is strictly positive, this means that the constraint is binding so that $A_{K,t} = 0$. Given prices, policies and transfers $\{P_t, i_t, W_t, T_t\}$, the Keynesian households choose the set of processes $\{C_{K,t}, N_{K,t}, M_{K,t}, A_{K,t}\}$ to maximize (1) with respect to (6) and (7), which yields the following first-order conditions:

$$C_{K,t}^{-1} = \beta_K \mathbb{E}_t \left[\frac{1 + i_t}{\pi_{t+1}} C_{K,t+1}^{-1} \right] + \phi_t \quad (8)$$

$$\frac{\psi_K N_{K,t}^\varphi C_{K,t}}{1 - \chi} = w_t (1 - \tau_t) \quad (9)$$

$$\frac{M_{K,t}}{P_t} = \left(\frac{\chi}{1-\chi} \right) C_{K,t} \left(1 + \frac{1}{i_t} \right) \quad (10)$$

The inter-temporal equation (8) is called the Keynesian Euler equation, the equation (9) is the Keynesian labor supply, and the equation (10) is the Keynesian money demand. At the steady state, we have $C_{K,t} = C_{K,t-1} = C_K$ in the Euler equation, $\pi_{t+1} = \pi = 1$ (steady state without inflation), $1 + i_t = \frac{1}{\beta_R}$ due to the Ricardian Euler equation (3), so that the Keynesian Euler equation (8) becomes

$$C_K^{-1} \left[1 - \frac{\beta_K}{\beta_R} \right] = \phi$$

Since we assume that Ricardian households are more patient, we have $\beta_R > \beta_K$ and therefore $\phi > 0$: hence the constraint is binding so that we have $A_{K,t} = 0$. Moreover, the market clearing condition on assets implies $\lambda A_{K,t} + (1 - \lambda) A_{R,t} = 0$: this means that $A_{R,t}$ is also equal to 0. Then, in the rest of the document, we will consider that $A_{K,t} = A_{R,t} = 0$: note that Ricardian households still have financial savings since they own a part $B_{R,t}^H$ of the government debt, which is not null.

2.2 Firms

The economy is characterized by an infinite number of firms indexed by z on the unit interval $[0, 1]$. Each firm produces a differentiated variety with a decreasing return to scale technology

$$Y_t(z) = Z_t N_t(z)^{1-\alpha} \quad (11)$$

where $N_t(z)$ is the amount of labor hired by the firm z at the period t , α is the labor income share parameter and Z_t denotes the Total Factor Productivity (TFP) following the law of motion

$$Z_t = 1 + \rho(Z_{t-1} - 1) + \varepsilon_t^Z$$

where ρ is a persistence parameter for the productivity shock ε_t^Z . Each firm is subject to quadratic price adjustment costs $X_t = \frac{\theta}{2} \left(\frac{P_t(z)}{P_{t-1}(z)} - 1 \right)^2$ expressed in the unit of consumption goods, as in Rotemberg (1983). This adjustment cost creates

a nominal rigidity in the model, governed by the rigidity parameter $\theta > 0$: it means that prices will not adjust immediately following a shock, and the effects of the shock will gradually decline over several periods. The profit of the firm z at each period is then given by the difference between the value of the output produced, the labor cost and the adjustment cost, so that the intertemporal nominal profit writes

$$\mathbb{E}_t \sum_{i=0}^{\infty} Q_{t,t+i} [P_{t+i}(z)Y_{t+i}(z) - W_{t+i}N_{t+i}(z) - P_{t+i}X_t] \quad (12)$$

where $Q_{t,t+i}$ is the discount factor of the profit at $t+i$ in period t . We assume that this discount factor is equal to the discount rate of Ricardian households, *i.e.* $Q_{t,t+i} = \beta_R^i \frac{C_{R,t}}{C_{R,t+i}\pi_{t+i}}$ (our results would be the same if we simply use $Q_{t,t+i} = \beta_R^i$). Moreover, we assume that a representative firm under perfect competition produces the single final good with a constant returns technology

$$Y_t = \left(\int_0^1 Y_t(z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

The profit maximization of the representative firm implies that the demand faced by each intermediary firm is equal to

$$Y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\varepsilon} Y_t \quad (13)$$

Since all firms z operate in monopolistic competition, they choose the processes $\{P_t(z), N_t(z), Y_t(z)\}$ to maximize (12) subject to (11) and (13) and taking as given aggregate prices and quantities $\{P_t, N_t, Y_t\}$. All firms are identical, then profit maximization implies that all firms choose the same price, *i.e.* $P_t(z) = P_t$, so that the inflation evolves according to

$$\pi_t(\pi_t - 1) = \beta_R \mathbb{E}_t \left[\frac{C_{R,t}}{C_{R,t+1}} \pi_{t+1}(\pi_{t+1} - 1) \right] + \frac{\varepsilon Y_t}{\theta} \left(\frac{w_t}{\mu_t} - \frac{\varepsilon - 1}{\varepsilon} \right) \quad (14)$$

where μ_t is the marginal productivity of labor equal to $(1 - \alpha)Z_t N_t^{-\alpha}$. This equation is the Phillips curve: current inflation depends positively on current marginal costs and on expected future inflation. At the steady state without inflation, we get

$w = \mu \frac{\varepsilon-1}{\varepsilon}$: since $\varepsilon > 1$, this means that we get a markup between wage and the marginal productivity of labor, which creates profits. Finally, the aggregate real profits and dividends are given by

$$D_t = Y_t - w_t N_t - \frac{\theta}{2} (\pi_t - 1)^2 \quad (15)$$

Note that at the steady state, we get $D = \frac{1+\alpha(\varepsilon-1)}{\varepsilon} Y > 0$: the monopolistic competition implies positive profits, which creates a transmission channel that will be important in our model. Indeed, if wage increases following a given shock, other things being equal, both Ricardian and Keynesian households will earn more, but since dividends will decrease, Ricardian household will also have a negative effect through the dividend channel, possibly higher than the direct effect of wage increase. Then, other things being equal, an increase in wage leads to a reduction of consumption inequality in our model.

2.3 Fiscal Authority and Monetary Authority

The **fiscal authority** in our model, or government, collects labor taxes τ_t , receives real transfer S_t from the central bank and issues one-period riskless government nominal debt B_t to finance exogenous public expenditures \bar{G} and repay its last period debt B_{t-1} with interests i_{t-1} . Since the focus of our analysis is about monetary policy and therefore central bank, the government does not play a very active role in our model. The government budget constraint at period t is given by

$$P_t \bar{G} + B_{t-1}(1 + i_{t-1}) = (1 - \lambda) \tau_t W_t N_{R,t} + \lambda \tau_t W_t N_{K,t} + P_t S_t + B_t \quad (16)$$

We assume that the government targets a real value of debt $B_t = \bar{B}$ and public expenditures \bar{G} which will be chosen to match the ratio debt-to-GDP and public spending-to-GDP in Europe. Finally, to close the government budget constraint, we assume that taxes τ_t simply adjust to match the changes in central bank transfer S_t .

The important part of our model is the **monetary authority**, or the central bank. In most models, central bank is assumed to meet its target, either on inflation

or output gap, by controlling nominal interest rate through the Taylor rule. In our model, this conventional tool is replaced by the direct control of money supply. The central bank can issue new reserves $\Delta M_t = M_t - M_{t-1}$ and use it for monetary policy purposes, either by giving the money directly to people (helicopter money) or by buying government debt to households (quantitative easing). In either case, the money creation is supposed to follow an AR(1) process in the growth rate with the following rule:

$$\frac{M_t - M_{t-1}}{M_{t-1}} = (1 - \phi_m)(\bar{\pi} - 1) + \phi_m \frac{M_{t-1} - M_{t-2}}{M_{t-2}} + \varepsilon_t^M \quad (17)$$

In this rule, $\bar{\pi}$ is the inflation targeted by the central bank. At the steady state where $\frac{M_t - M_{t-1}}{M_{t-1}} = \frac{M_{t-1} - M_{t-2}}{M_{t-2}} = \hat{m}$, this rule means that $\hat{m} = \bar{\pi} - 1$, so that the growth rate of money is equal to the targeted inflation (recall that $\bar{\pi}$ is the gross inflation rate, equal for example to 1.02 if the targeted inflation is 2%). In this rule, $\phi_m \in [0, 1]$ is a persistence coefficient: a shock ε_t^M in the growth rate at the period t still has an effect of ϕ_m at the period $t + 1$, ϕ_m^2 at the period $t + 2$, and vanishes after some periods since $\phi_m < 1$. This means that a monetary shock ε^M will create a total increase of $\frac{1}{1 - \phi_m} \varepsilon^M$ in the money supply. The main point of our paper is to see the effect of this shock in our economy: the baseline value for this shock will be calibrated in the following experiments such that the initial new money ΔM_t is equal to 1% of the steady state output. The central bank uses the new created money in two different ways: a fraction $x \in [0, 1]$ is transferred directly to households through the transfer T_t (we call this scenario "helicopter money") and a fraction $1 - x$ is used to increase the central bank government debt holding B_t^M by purchasing public bonds to households (we call this scenario "quantitative easing"). In both cases, new money will be held by households, but the effects will be different since helicopter money is equally distributed among all people, whereas quantitative easing goes to Ricardian households who are the only ones to hold government debt. Formally, these two scenarios writes

$$P_t T_t = x \Delta M_t \quad (18)$$

$$B_t^M = B_{t-1}^M + (1 - x) \Delta M_t \quad (19)$$

Moreover, we suppose that the central bank does not make any profit and transfers to the government the interests it receives from its debt holding. The transfer S_t to the government is then equal to

$$P_t S_t = i_{t-1} B_{t-1}^M \quad (20)$$

This transfer creates an indirect effect that is specific to quantitative easing: when the central bank owns the public debt, it lowers the debt service for the government, because the government pays the interest only on the debt held by households. Then it reduces taxes paid by households, which has a positive effect on the economy. However, this effect is extremely small: if the central bank increases by 1% its public debt holding, and if the interest rate is 1%, then the tax rate will decrease by $0.01 * 0.01 = 0.0001$, which is negligible. Finally, the previous equations lead to the following budget constraint for the central bank:

$$B_t^M + P_t S_t^G + P_t T_t = B_{t-1}^M (1 + i_{t-1}) + \Delta M_t \quad (21)$$

Note that, at the steady state, the transfer to government is equal to $S = ib^M$ with $b^M = \frac{B^M}{P}$ the real value of the steady state central bank debt holding, and the tax rate is equal to $\tau = \frac{\bar{G} + ib^H}{wN}$, *i.e.* the public spending and the service of the debt divided by the aggregate labor income.

2.4 Markets clearing conditions and equilibrium

Finally, to close the model, we have the following market clearing conditions for goods, debt, consumption, money and labor:

$$Y_t = C_t + G + \frac{\theta}{2} (\pi_t - 1)^2 \quad (22)$$

$$B = (1 - \lambda) B_{R,t}^H + B_t^M \quad (23)$$

$$C_t = \lambda C_{K,t} + (1 - \lambda) C_{R,t} \quad (24)$$

$$M_t = \lambda M_{K,t} + (1 - \lambda) M_{R,t} \quad (25)$$

$$N_t = \lambda N_{K,t} + (1 - \lambda) N_{R,t} \quad (26)$$

Given laws of motion for the exogenous states $\{\varepsilon^M, A\}$, the equilibrium is defined as joint law of motion for households' choices $\{N_{i,t}, C_{i,t}, B_{i,t}^H\}_{i \in \{R, K\}}$, government and central bank choices $\{\tau, G, S, T, M\}$, aggregate quantities $\{Y, N, C\}$, prices and dividends $\{\pi, D\}$, such that $\forall t$,

- (i) Each household $i \in \{R, K\}$ maximizes (1) subject to the constraints (2), (6) and (7);
- (ii) Firms in total produce $Y_t = Z_t N_t^{1-\alpha}$, pay out dividends according to (15), and set nominal prices such that the New Keynesian Phillips Curve (14) holds;
- (iii) The government's and central bank's budget constraints, (16) and (21), hold;
- (iv) The central bank conducts the monetary policy according to (17), (18), (19) and (20);
- (v) all markets clear, according to (22) to (26).

3 Helicopter money and quantitative easing

3.1 Calibration

Before we start showing the results from our experiments, we describe the calibration for each parameter, and we summarize it in the Table 1. In the sensitivity analysis later in this document, we consider alternative calibrations for the main parameters.

We target a labor supply equal to $N = N_R = N_K = 1/3$ at steady state, so that we calibrate the parameters scaling the disutility of labor ψ_R and ψ_K to respectively 300 and 701. This gives us the steady state level of output (equal to 0.44); we target a ratio of government expenditures to output of 25 percent, in line with national accounts data, and a ratio of debt to output of 98 percent, which is the average in Europe after the Covid crisis. We assume that the central bank targets zero inflation in the steady state, *i.e.* $\pi = 1$. We calibrate the labor income share $1 - \alpha = 0.75$ which is similar to values found in the literature and in Galí (2014). Since $w = \mu \frac{\varepsilon-1}{\varepsilon}$ at the steady state, we calibrate $\varepsilon = 8$ to have a steady-state markup of 12.5 percent. We set $\beta_R = 0.995$, which corresponds to an annual

interest rate of two percent; β_K is set to 0.95 as in Bilbiie, Monacelli and Perotti (2013). The inverse Frisch elasticity of labor supply φ is set to 5 as in Gali (2014), which implies a Frisch elasticity equal to 0.2. The weight of the money in the utility function, χ , is set to 0.0377 to match the ratio between quarterly consumption and the monetary aggregate M3 in Europe. The price adjustment cost parameter is set to $\theta = 47.1$, which corresponds to an average price duration of three quarters in the Calvo equivalent of the model. The share of Keynesian agents is set to 0.35 as in Bilbiie, Monacelli and Perotti (2013). Finally, the persistence coefficients for monetary and productivity shocks are set to $\phi_M = 0.5$ and $\rho = 0.9$, as in Cui and Sterk (2019).

Table 1: Parameter values and steady-state targets.

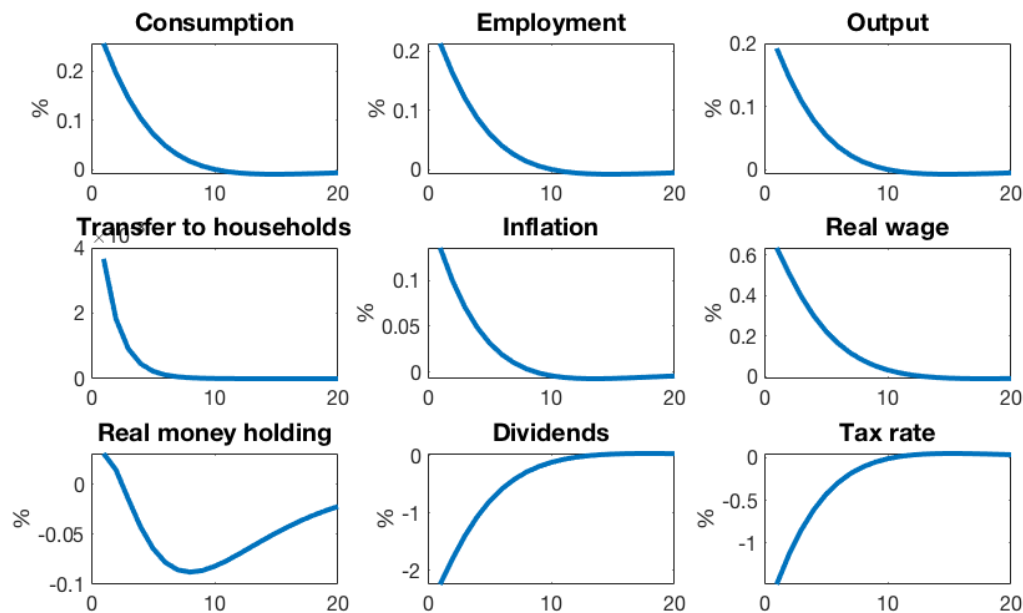
Parameter	Description	Value	Notes
β_R	Ricardian subjective discount factor	0.995	annual interest rate: 1%
β_K	Keynesian subjective discount factor	0.95	
ψ_R	labor disutility parameter for Ricardian	300	average labor supply: 1/3
ψ_K	labor disutility parameter for Keynesian	701	average labor supply: 1/3
φ	inverse Frisch elasticity	5	convention
χ	weight of money in the utility function	0.0377	ratio quarterly consumption / M3 : 0.12
\bar{G}	real government expenditures	0.11	expenditures-to-annual-output: 25%
\bar{B}	real debt	0.43	average debt-to-output ratio in Europe: 98%
α	labor income share parameter	0.25	labor income share: 75%
ε	elasticity of substitution varieties	8	markup: 12.5%
θ	price adjustment cost parameter	47.1	average price duration: 3 quarters
ϕ_M	persistence of monetary shock	0.5	
ρ	persistence of productivity shock	0.9	
$\bar{\pi}$	long-run inflation target	1	net inflation rate: 0%

3.2 Helicopter money

We are now able to simulate our model using the calibration above. All the impulse response functions shown below are the response of variables to a money creation shock ε_t^M in the money rule calibrated to be equal to 1% of the steady

state output, *i.e.* $\Delta M_t = 1\%Y$. Since the persistence coefficient of the shock is equal to $\phi_M = 0.5$, this means that the total of the new money created is equal to 2% of the steady state output. All results are in % deviation from steady state level (vertical axis) and the unit of time is one quarter (horizontal axis).

Figure 1: Response of aggregate variables after a helicopter money shock

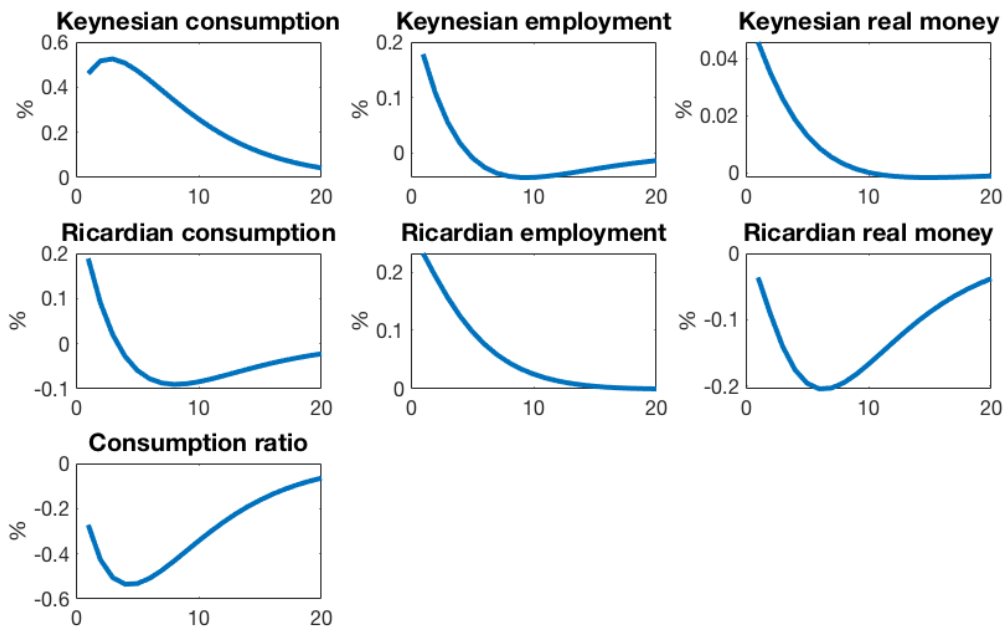


As we see in the Figure 1, a money creation ΔM_t initially equal to 1% of steady state output triggers an increase of 0.25% in aggregate consumption, 0.21% in hours worked and 0.19% in output on impact: people have more money, the aggregate demand increases, so that output and employment increase to match this new demand. These increases in labor demand and good demand lead to a 0.14% increase in inflation and 0.66% in real wage. Since real wage increases more than inflation, dividends decrease by 2%. Finally, the tax rate decreases by 1.4%, because the general taxable labor income increases whereas government spending are still fixed. All these effects decrease with time and economy goes back to its steady state level. If we compute the sum of responses to this total 2% of GDP money creation, we get that GDP increases by 0.6%, consumption by 0.8% and

inflation by 0.4%. These results rely heavily on the persistence of the monetary shock: with $\phi_M = 0.9$ instead of 0.5, as we will see later in the sensitivity analysis, the total (and instantaneous) effects would be much higher. Still, this first figure gives us important insight into the effect of helicopter money: **helicopter money yields sizable effects on aggregate variables, and the "gain" of this monetary policy, i.e. the increase in consumption, is higher than the "cost", i.e. the increase in inflation.**

Another key dimension of our model is the heterogeneity between households. The previous graph teaches us nothing about the effect of helicopter money on both types of households, even if we can make some guess: since the real wage increases for both agents, and since dividends decrease only for Ricardian households, we can imagine that helicopter money reduces consumption heterogeneity, increases Keynesian consumption, and the effect on Ricardian consumption is indeterminate a priori. The following figure 2 presents the impulse response functions for disaggregated variables:

Figure 2: Response of disaggregate variables after a helicopter money shock



The first row presents the variables $C_K, N_K, \frac{M_K}{P}$ for Keynesian households. Keynesian consumption increases by 0.5% and employment by 0.2% on impact. The employment response is even slightly negative at one point, because the agent prefers to reduce its employment since its consumption is still high (*i.e.* at some point, the wealth effect dominates the substitution effect induced by the increase in real wage). Then helicopter money has a positive effect on Keynesian households: the direct effect of the transfer and the wage increase triggers a substantial increase of the Keynesian consumption. The second row presents the variables $C_R, N_R, \frac{M_R}{P}$ for Ricardian households. Ricardian consumption increases by 0.18% and employment by 0.23% on impact. However, consumption response becomes negative at one point. As we mentioned above, this is due to the dividend channel: while both agents enjoy the increase in wage and the transfer from the central bank, the decrease in dividends is supported only by Ricardian households who own the firms. The rigidity in our model creates a long-lasting increase in wages (and then a long-lasting decrease in dividends), whereas the positive effect of the transfer is much shorter due to the low persistence of the monetary shock. Then, on the three effects induced by helicopter money (direct effect of the transfer, increase in wage, decrease in dividends), the two first benefit equally to all households, whereas the third triggers a negative consumption response only for Ricardian agents. This is reflected in the last graph of the figure 2, which is the consumption ratio between Ricardian and Keynesian households equal to $\frac{C_{R,t}}{C_{K,t}}$. At the steady state, this ratio in our model is equal to 1.6, which means that Ricardian households consume 60% more than Keynesian households. We interpret this parameter as a very stylized measure of inequality: as we see, it decreases up to 0.5% after 4 periods. This means that helicopter money, through the effects mentioned above, reduces inequality and benefit mostly to Keynesian households.

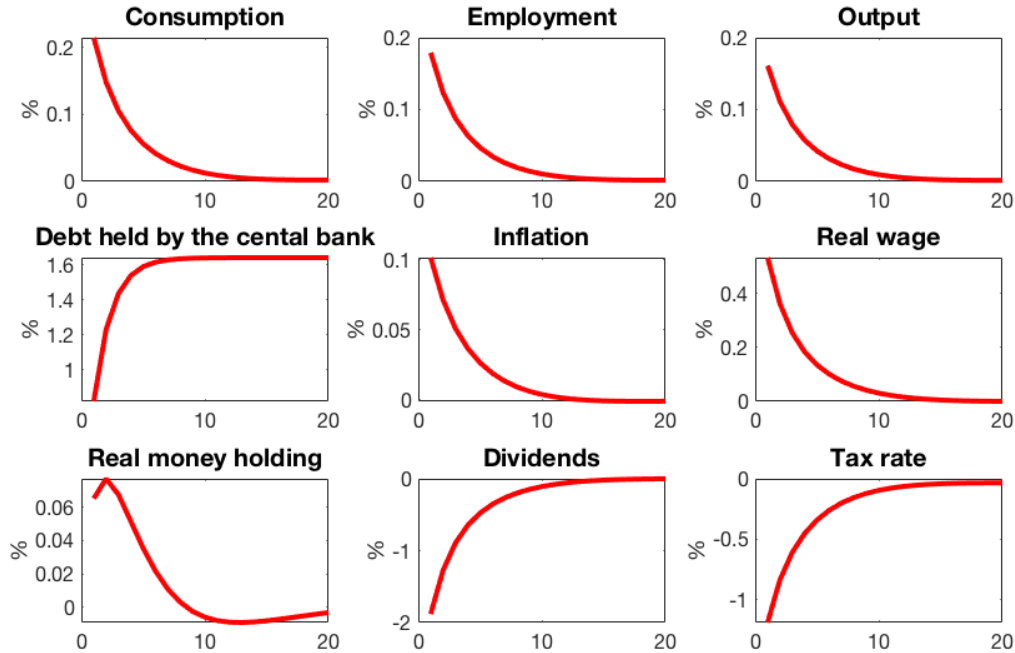
At this point, we have seen that helicopter money, *i.e.* money creation transferred to all households, has a significant impact on output and consumption, and that inflation is almost half less responsive than aggregate consumption. Moreover, the benefits of helicopter money are higher for Keynesian households, because dividends fall for Ricardian agents. We now have to compare this hypothet-

ical monetary policy with the quantitative easing policy that has been used since 2008.

3.3 Helicopter versus QE

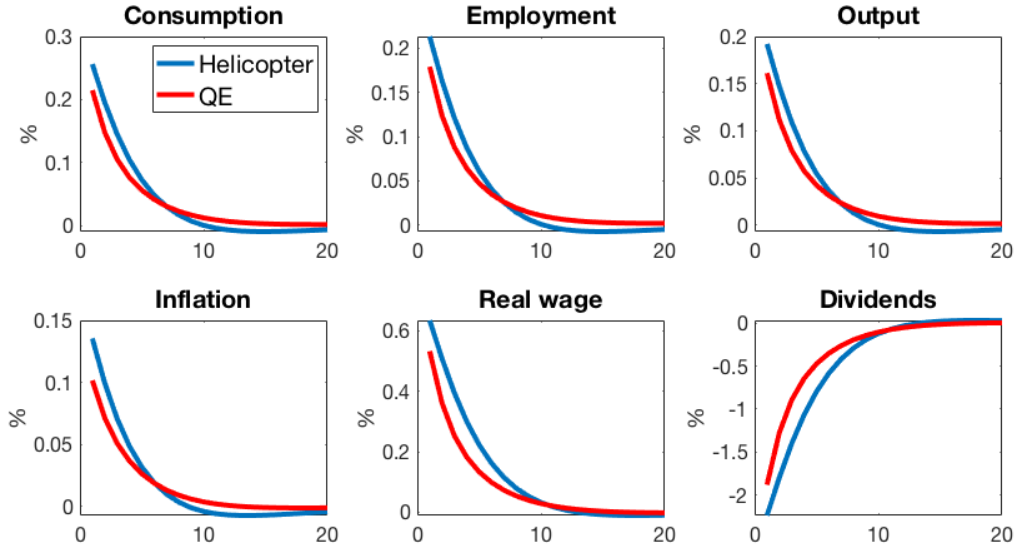
As we have seen above, the helicopter money is a combination of three effects: the direct effect of the transfer which relaxes the budget constraint, the general equilibrium effect on employment and wage due to the increase in aggregate demand, and the dividends channel that concerns only Ricardian households since they own all the firms. The quantitative easing is different: the money created is not transferred to households, but used by the central bank to purchase government debt from Ricardian households. This purchase replaces an illiquid asset, the government bond, by a liquid asset, money: this creates an increase in Ricardian demand, an increase in employment and output to match the demand, and then an increase in wage that benefits to all households, especially Keynesian households that did not receive money from the QE in the first place. Hence in QE and as opposed to helicopter money, the direct effect is only for Ricardian households, whereas the general equilibrium effects are for everyone, but may be smaller than previously due to the lower MPC for Ricardian households. The following graphs show the impulse response functions of the aggregate variables after a QE shock, calibrated to be equal to 1% of the steady state GDP as previously. Since the government debt is equal to 98% of GDP, this means that the central bank acquires almost 1% of the public debt on impact, and about 2% in total.

Figure 3: Response of aggregate variables after a QE shock



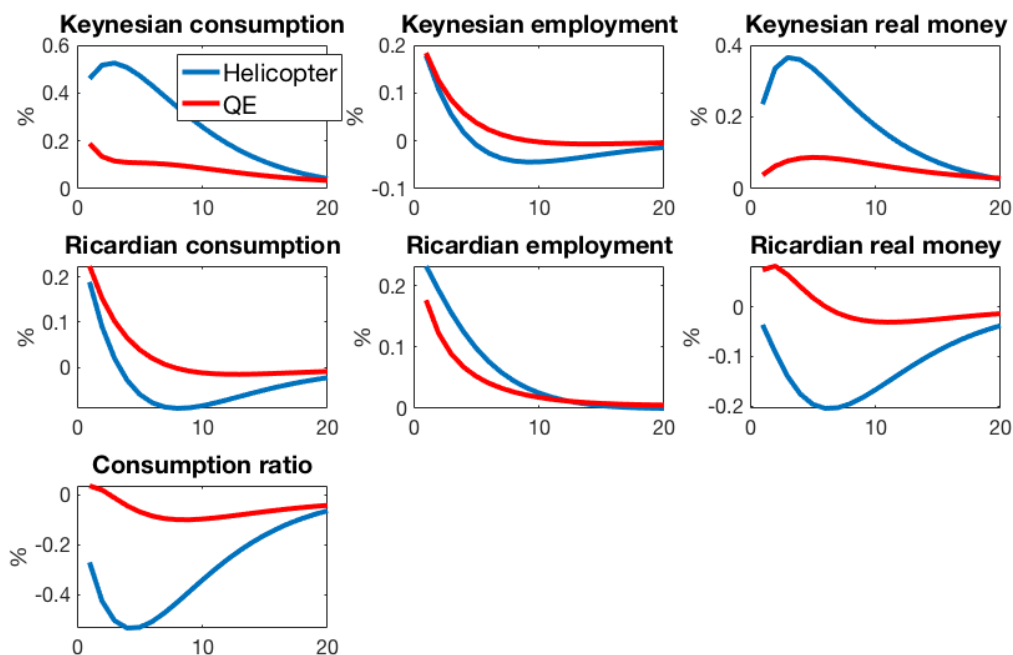
As we see in the figure 3, the responses of aggregate variables after a QE shock are slightly below those for helicopter money on impact, with an increase of aggregate consumption by 0.21%, 0.10% in inflation and 0.16% in output (against 0.25, 0.14 and 0.19 with helicopter money). This result is logical: since all the new created money is concentrated on Ricardian households, and since they have a marginal propensity to consume smaller than the average population due to their high discount factor, all the aggregate effects are reduced compared to helicopter money. The figure 4 illustrates the slight difference between these policies:

Figure 4: Comparison between QE and helicopter, aggregate variables



On impact and during some periods, helicopter money triggers a higher reaction than QE. However, after some periods, consumption, output and inflation are higher in the QE scenario: this is due to the fact that since the central bank owns part of the public debt, the debt service decreases for the government (because it does not pay interests on the debt held by the central bank), so taxes decrease slightly. Hence QE and helicopter are comparable in their overall magnitude: helicopter money creates a slightly higher reaction on impact, and QE lasts a bit longer. However, the true difference between QE and helicopter money appears when we look at disaggregated variables as in the figure 5.

Figure 5: Comparison between QE and helicopter, disaggregate variables



If the figure 4 can make us think that QE and helicopter money are approximately equivalent, figure 5 tells a completely different story. As we see, quantitative easing is biased towards Ricardian households: while helicopter increases Keynesian consumption more than QE, it is the opposite for Ricardian consumption. Indeed, Ricardian consumption response turns out to be even negative with quantitative easing: the increase in real wage and the transfer do not compensate the fall of dividends induced by helicopter money, so that the Ricardian consumption decrease. The comparison between the two first rows are striking: QE and helicopter money are almost symmetrical with respect to both types. Yet we can note that the Keynesian consumption increase following helicopter is twice higher in magnitude than the Ricardian consumption increase following quantitative easing (0.46% against 0.22%). Finally, the difference between both policies is captured by the last graph of the figure 5: the consumption ratio, which is our measure for inequality, decreases strongly with helicopter money but much less with quantitative easing.

Overall, we have seen that quantitative easing yields similar results as helicopter money for aggregate variables: the small difference is that QE effect is slightly weaker on impact, but lasts longer. However, the effects of both policies on disaggregate variables are different: quantitative easing is biased towards Ricardian households, whereas helicopter money increases Keynesian consumption and reduces the consumption ratio.

3.4 Sensitivity analysis and robustness

Before assessing the effects of the quantitative easing program in Europe since 2008, we briefly discuss the robustness and the sensitivity analysis of the impulse response functions presented above. For the sake of brevity, the IRFs we discuss in this section are presented in the appendix. We mainly focus on three parameters: the weight of money in the utility function χ , the persistence parameter ϕ_M and the price rigidity θ , and we also compute for each calibration the cumulative consumption multiplier $(1 - \phi_M) \sum_{t=0}^{\infty} \hat{c}_t$.

The **weight of money** in the utility function χ governs the ratio between quarterly consumption and monetary aggregate at the equilibrium. In the baseline calibration, we have used the value $\chi = 0.0377$ to match the ratio "quarterly consumption over M3", equal to 0.12 in Europe. However, Punzo & Rossi (2016) use $\chi = 0.08$ in their utility function. A higher value means that households value more money compared to consumption so that, when the central bank transfers money to households, they increase their money holding and less their consumption. Then we can expect that, the higher χ , the lower the effects of helicopter money. In the figure A1 in appendix, we compute the impulse response functions for three values of χ : $\chi = 0.02$, $\chi = 0.0377$ and $\chi = 0.08$. As we expected, all the responses are smaller when χ increases, with the cumulative consumption multiplier respectively equal to 0.64, 0.30 and 0.12. Then on impact and cumulatively, our responses and our results are inversely proportional to χ . However, our baseline calibration for χ may be already an upper bound, since we have chosen M3 as the empirical counterpart: our χ would have been smaller using M2, M1 or even M0, and then our responses would have been higher.

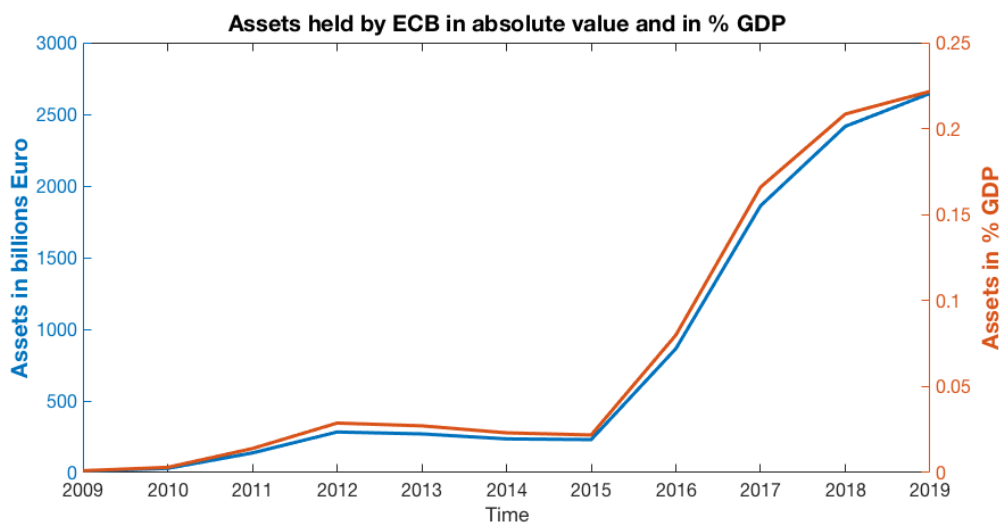
The **persistence** ϕ_M of the monetary shock is important as it directly governs the quantity of new money created. Indeed, if we introduce a shock on money creation equal to 1% of steady state output, a persistence equal to $\phi_M = 0.5$ implies a total amount of new money equal to 2% of steady state output, whereas $\phi_M = 0.9$ implies a value of 10%. We may expect that, the higher the persistence, the higher the response, both on impact and during the whole period. In the figure A2 in appendix, we compute the impulse response functions for three values of ϕ_M : $\phi_M = 0.2$, $\phi_M = 0.5$ and $\phi_M = 0.9$. Not surprisingly, we find that the effect is higher with a higher persistence. However, the cumulative consumption multiplier, which relates the total effects with the total size of the shock, is respectively equal to 0.31, 0.30 and 0.27, which means that the cumulative gains are almost proportional to the cumulative new money created. The policy implication of this result is that, according to the model, we will reach the same cumulative gains if we give the same amount of money in one transfer, or distribute it over time.

Finally, the non-neutrality of money in our model comes from the fact that there is **price adjustment cost**, which creates a nominal rigidity, because firms gradually adjust their prices over time instead of fully absorbing the rise in money supply by increasing proportionally prices. The higher the price adjustment cost, the higher the rigidity, so that inflation is less reactive on impact (if it is too costly to adjust prices, the inflation will rise much more gradually), but consumption and output are much more reactive on impact, because the money supply increases a lot but not the prices, so the purchasing power increases. In the figure A3 in appendix, we compute the impulse response functions for three values of θ : $\theta = 0$ (no rigidity, full flexibility), $\theta = 47.1$ (baseline, average price duration: 3 quarters) and $\theta = 300$ (high rigidity). As we see, with fully flexible prices, all the new money created is absorbed by the rise in inflation, so that the change in output and consumption is small. At the opposite, when the rigidity is high, the response is more important than in the baseline. This translates into higher multiplier with higher rigidity, with a cumulative consumption multiplier equal to respectively 0.02, 0.30 and 1.04. Then the monetary policy is increasingly efficient when the rigidity increases.

4 Estimation of the efficiency of QE in Europe since 2008

Until now, we have computed our experiments by simulating a money creation shock equal to 1% of steady state output, with a baseline persistence of 0.5. While the theoretical results for helicopter money and quantitative easing are interesting, we must go back to data and calibrate the size of the shock according to the actual assets purchase program conducted by the European Central Bank since 2008. In this section, we use for our analysis ECB data about GDP in the Euro area and about securities held for monetary policy purposes in the Eurosystem¹. As we see in figure 6, the first ECB quantitative easing program started in 2009 until 2012 (at 283 billion and 3% Euro GDP), before being renewed and significantly increased in 2015 until today. In 2019, ECB holds 2650 billion Euro assets representing 22% of GDP in Europe; we stop our analysis at 2019 to avoid perturbations due to Covid crisis, but in April 2021 the ECB holds 3936 billion Euro assets, which is a massive increase.

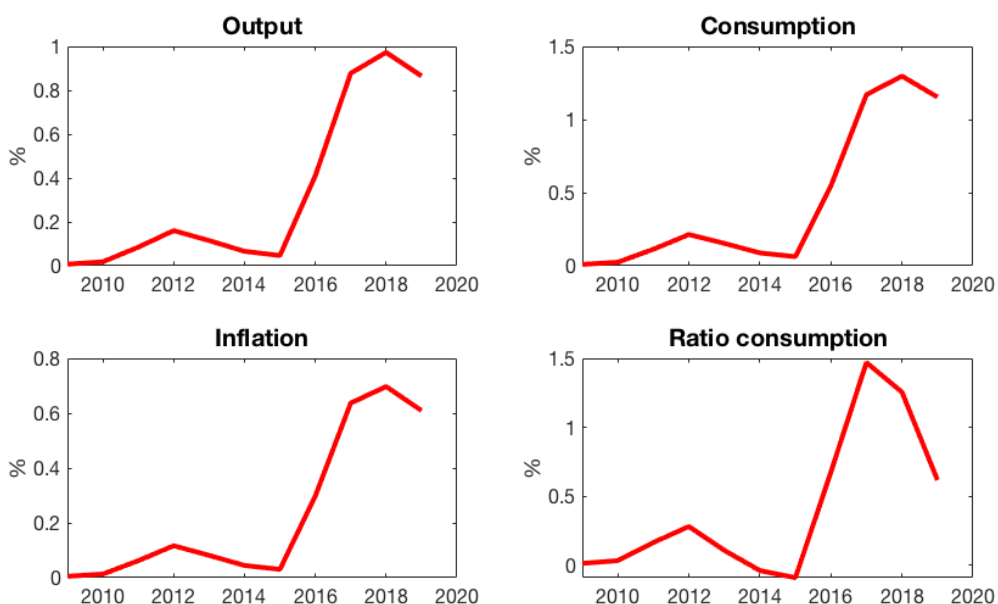
Figure 6: Assets held by central bank in absolute value and in % GDP



¹https://sdw.ecb.europa.eu/quickview.do?SERIES_KY=123.ILM.W.U2.C.A070100.U2.EUR

Considering the ECB assets purchase program as a flux rather than a stock (*i.e.* we consider the change in ECB assets holding over time relative to GDP), we are able to simulate the effect of quantitative easing between 2009 and 2019. We replace in our model the monetary shock ε^M by the actual sequence of assets purchase in % output, and we set the persistence at $\phi_M = 0$. We obtained the estimated effect of quantitative easing between 2009 and 2019 in Europe that we plot in the figure 7.

Figure 7: Estimated effect of QE between 2009 and 2019

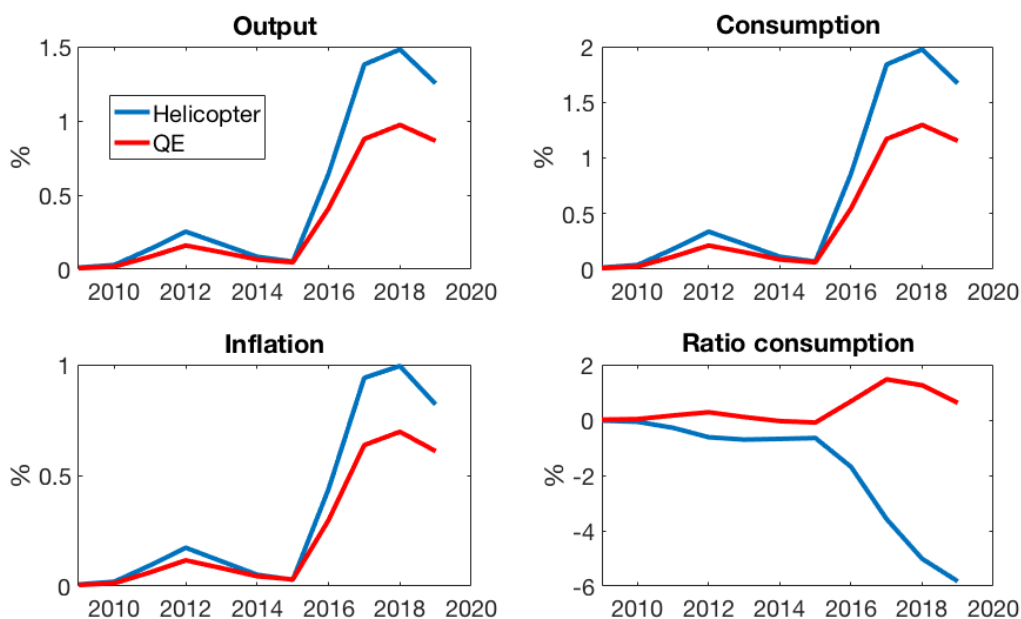


As we see, the assets purchase program of the ECB has a significant effect on inflation, output and consumption between 2009 and 2019. The size of the program was small between 2009 and 2015: the pick of 2012 contributed to an increase of 0.21% in consumption and 0.12% in inflation. As we see, inflation is almost twice less responsive than inflation. However, after 2015, the QE program became much more important, and contributed to sizable increase of GDP by 1%, consumption by 1.3% and inflation by 0.7% in 2018, the year the ECB bought the most assets. To compare with the existing literature, Hohberger et al. (2019) compute that the

QE increased GDP by 0.3% and inflation by 0.5% on average between 2015 and 2019: we find an increase of respectively 0.6% and 0.5% on the same period. However, as we explained previously, QE is biased towards Ricardian agents, so that it increased consumption heterogeneity between 2009 and 2019 by about 1%.

After the estimation of the effects of QE since 2009, we now estimate what could have been the effects of the same amount of money creation, but distributed through helicopter money rather than quantitative easing. Then we estimate the same model and the same sequence of shock, but money is distributed directly to all households by transfers. The results of this experiment and the comparison with QE are reported in figure 8.

Figure 8: Estimated effect of helicopter and QE between 2009 and 2010



We have seen previously that the effect of helicopter money was higher than QE on impact, because QE targets households with lower marginal propensity to consume than average. The figure 8 shows us what could have been the magnitude of this difference, if we have used helicopter money instead of QE between 2009 and 2019. Before 2015, this difference is small, but it increases significantly after:

in 2018, helicopter money could have increased output by 0.5%, consumption by 0.7% and inflation by 0.2% (which, in this case, is not necessarily a gain) compared to QE. Overall, if we sum the responses, **we estimate that QE has contributed to increase output, consumption and inflation by respectively 3.6%, 4.8% and 2.6% between 2009 and 2019, while helicopter money could have contributed to increase these variables by respectively 5.5%, 7.3% and 3.7% in the same period.** Moreover, the important difference between these two unconventional monetary policies relates to heterogeneity between households. As we have seen before, helicopter money is more equal than QE by construction. While we estimate that QE has contributed to increase the consumption ratio, our very stylized measure of inequality, by about 1%, helicopter money would have reduced this ratio by almost 6%. Then helicopter money would have yield higher gains than QE in terms of consumption and output, and higher costs in term of inflation (if we admit that inflation is bad, which is not necessarily the case since the central bank has trouble reaching its 2% target). Moreover, helicopter money could have reduced inequality, where quantitative easing has increased it.

5 Welfare analysis

We have computed in section 3 the effects of helicopter money and quantitative easing in our model for a baseline money creation shock equal to 1% of steady state output, with a persistence equal to 0.5. We now turn to the welfare analysis of this shock, *i.e.* we try to estimate if these policies increase the welfare of households. We have two ways to evaluate the welfare: compute the consumption equivalence, or use a utilitarian criterion.

Consumption equivalent

The idea behind the "consumption equivalent" is to answer the question: what is the permanent increase in consumption that gives me the same utility as the policy? Or, equivalently, by how much do you agree to decrease your consumption, forever, to get the policy? We need to compute the permanent increase in con-

sumption such that the infinite discounted sum of utility derived from consumption is equal to the utility following the shock. In mathematical terms, denoting $c_{i,t}^{\text{shock}}$ the consumption path of type i following a baseline shock of money creation equal to 1% of steady state output, and c_i^{SS} the steady state level of consumption of type i , this means that we compute the consumption equivalence (denoted CE) such that $\sum_{t=0}^{\infty} \beta_i^t \log(c_i^{\text{SS}} + \text{CE}) = \sum_{t=0}^{\infty} \beta_i^t \log(c_{i,t}^{\text{shock}})$. For both types (Keynesian and Ricardian) and for both policies (QE and helicopter money), we then compute the consumption equivalence of the monetary policy.

For **quantitative easing**, we have seen in Figure 5 that it increases Keynesian consumption by 0.2% on impact, and Ricardian consumption by 0.22%. Then we compute the consumption equivalent, and we find that the quantitative easing shock is equivalent to a permanent increase in consumption of **0.01% for Ricardian households**, and **0.52% for Keynesian households**. We may wonder why the consumption equivalent is much smaller for Ricardian than for Keynesian, while the shock is lower for the latter: this is because the Keynesian discount factor is much lower than the Ricardian one (0.95 against 0.995), so that the gain of the policy, available today, is more valued than the consumption increase in the future. Overall, we see that the quantitative easing benefits to both households, but the gain is negligible for Ricardian households. Of course, with a bigger shock or a higher persistence, the consumption equivalent increases.

For **helicopter money**, we have seen in Figure 5 that it increases Keynesian consumption by 0.5% on impact, and Ricardian consumption by 0.18%, but the latter responds negatively after some period. Then we compute the consumption equivalent, and we find that the helicopter money shock is equivalent to a permanent increase in consumption of **-0.03% for Ricardian households**, and **1.02% for Keynesian households**. This means that for Ricardian households, the decrease in consumption after some periods outweighs the gain on impact, so that they do not benefit from helicopter money, and they incur a (negligible) loss of consumption. However, for Keynesian households, the gain with helicopter money is twice higher than with quantitative easing : 1.02% against 0.52%.

Again, we find that helicopter money benefits more to Keynesian households

than quantitative easing. At the aggregate level, since the gain or loss for Ricardian households in both cases are negligible (0.01% and -0.03%), and since the gain for Keynesian households are twice higher with helicopter money, we might think that helicopter money is more welfare-enhancing than quantitative easing.

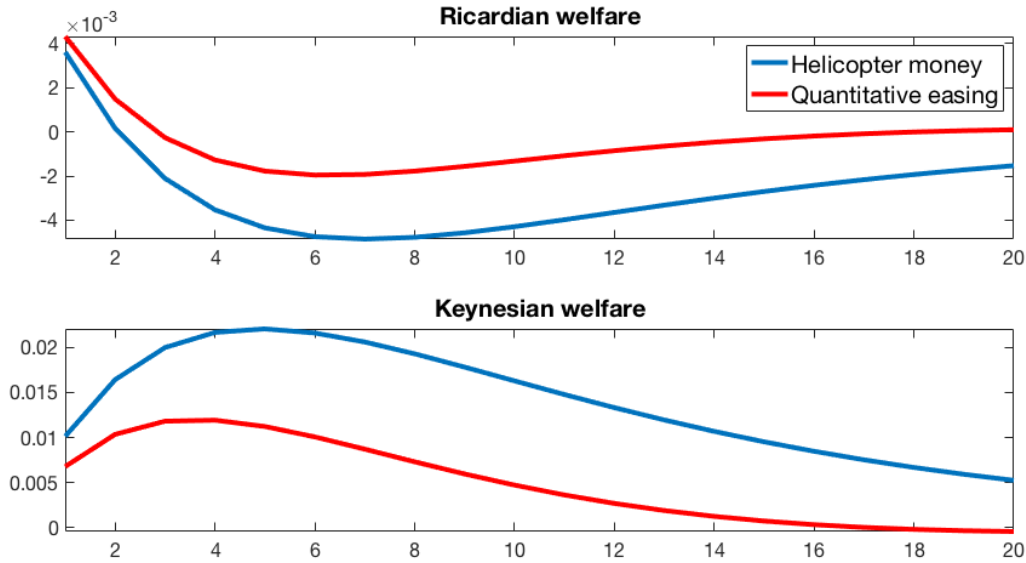
Utilitarian welfare

We have computed the consumption equivalent, which is a useful criterion in the sense that it directly reflects the value of a given policy in terms of consumption. However, it abstracts from the fact that, if we need to work a lot more to create a small increase in consumption, our welfare is likely to decrease, since in our framework individuals incur a disutility from labor. Then we can take this disutility into account by computing, at each time following a shock, the change in utility for each individual, with the following utility function:

$$U_i \left(C_i, N_i, \frac{M_i}{P} \right) = (1 - \chi) \ln C_i + \chi \ln \frac{M_i}{P} - \psi_i \frac{N_i^{1+\varphi}}{1+\varphi}$$

As we have seen in the Figure 5, employment increases for both Ricardian and Keynesian households following a monetary shock, because they need to work more to respond to the demand increase. If the disutility of this increase in employment outweighs the utility of the increase in consumption, the overall welfare is likely to decrease. We also take into account real money holding in the utility, but since χ is small, the effect of utility of a change in money holding is negligible. Then, following our baseline experiments for both policies, we draw the previous utility function for Ricardian and Keynesian households:

Utilitarian welfare following monetary policies



As we see, the Ricardian utilitarian welfare becomes negative after some periods, because the consumption response is negative following the decrease in dividends. The loss of welfare is more important in the case of helicopter money: if we sum the discounted utility until infinity, the change in the value function following quantitative easing is almost equal to 0 (-0.008) whereas the change in the value function following helicopter money is small but negative (-0.06). At the opposite, the Keynesian utilitarian welfare is always positive, and the change is much higher in magnitude than the change for Ricardian households. Again, we see that helicopter money yields higher gains than quantitative easing, about twice more important (as we have found for the consumption equivalent). Indeed, if we compute the change in value function, we find a total increase of 0.07 with quantitative easing, but 0.2 with helicopter money.

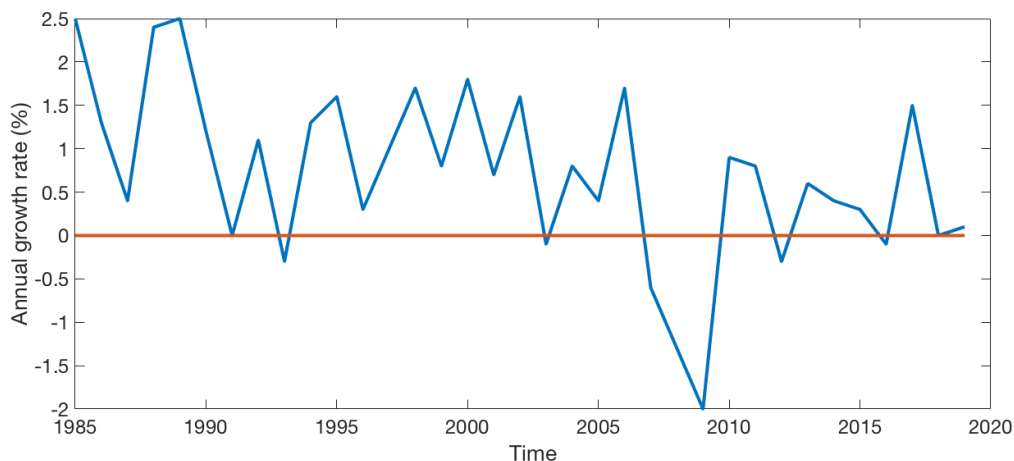
This utilitarian criterion, once again, points out the fact that the overall effect of both policies is very small for Ricardian households in magnitude: their consumption increases with quantitative easing, and decreases with helicopter money, and the overall effect on utilitarian welfare is always negative, but very small. However, both policies increase Keynesian consumption and Keynesian welfare.

Helicopter money is better than quantitative easing for Keynesian households, because the direct effect of the latter benefits only to Ricardian households, whereas Keynesian only benefit from general equilibrium effect. In magnitude, the gain for Keynesian households is 3 times higher than the loss for Ricardian households in the case of helicopter money, and 10 times higher in the case of quantitative easing.

6 Productivity shocks and optimal monetary policy

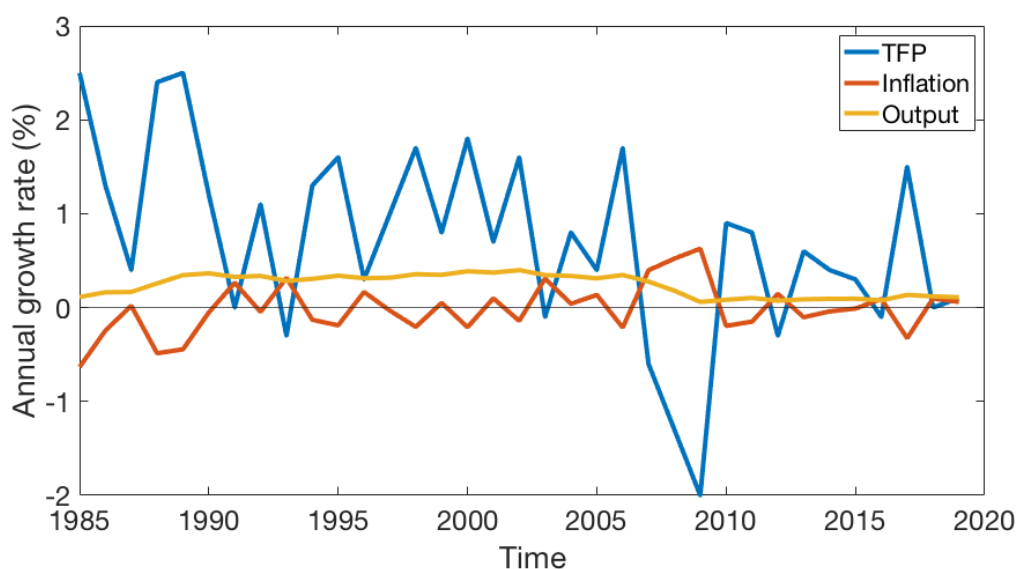
So far, we have considered monetary policy shocks, letting aside productivity shock in our Total Factor Productivity variable following the law of motion $Z_t = 1 + \rho(Z_{t-1} - 1) + \varepsilon_t^Z$. In this section, we simulate the responses of the main variables to an empirical sequence of productivity shocks, and we compute the optimal monetary policy to reduce the volatility of output and inflation. The best empirical counterpart to productivity shock is subject to many discussions: we choose to use the multifactor productivity growth rate in Europe, using OECD database between 1985 and 2019. We reproduce the annual growth rate on the following figure:

Figure 9: Annual growth rate of multifactor productivity in Europe



As we see, the productivity is volatile but generally increasing over years, with a drop during the subprime crisis. In our model, a productivity increase implies a cost reduction for the firm, which can now create more output with less input. This cost reduction flows through prices and reduces inflation, and firms reduce their labor demand, since less workers are necessary. Then wage decreases, and dividends increase. Overall, the consumption increases following a positive productivity shock, because the increase in dividends and the decrease in prices outweigh the decrease in wages and employment. We implement in our model the sequence of TFP shocks between 1985 and 2020 represented above, and we show in the following graph the response of inflation and output:

Figure 10: Annual growth rate of inflation and output in our model due to TFP shocks



As it is well known in this kind of model, the TFP shocks do not generate enough volatility of output and inflation, compared to empirical data (GDP growth is always between 0.3%, and inflation between -0.5 and 0.5%). If we want large business cycles, we need to add shocks on other variables, that are not present in our model. However, it should not prevent us to study fluctuations related only to TFP. As we see, TFP and inflation are negatively correlated, which is especially

visible at the TFP picks, for example in 1989, 2009 or 2017. At the opposite, productivity changes (majorly, productivity increases) trigger an increase in output by around 0.2% each year over the period considered. We see that inflation is more volatile than output: usually, volatility is viewed negatively by policy makers, as it creates uncertainty, crises, and reduces investment. If we consider that policy makers or central banks are averse to volatility in output and inflation, we can introduce the following loss function:

$$\mathbb{L}(\omega) = \omega \text{Var}(\widehat{Y}_t) + (1 - \omega) \text{Var}(\widehat{\pi}_t)$$

where \widehat{Y}_t is the output gap, $\widehat{\pi}_t$ is the inflation gap compared to the target, and the parameter ω describes the weight given to output volatility related to inflation volatility. We suppose for the sake of simplicity that the central bank puts the same weight on both volatilities, so that $\omega = 0.5$, or equivalently if we scale up, $\mathbb{L} = 100 \cdot \text{Var}(\widehat{Y}_t) + 100 \cdot \text{Var}(\widehat{\pi}_t)$. With this loss function, we are now able to simulate the loss implied by TFP shocks between 1985 and 2019, *i.e.* the loss associated to the previous graph. We find that $\mathbb{L} = 8.7$, with 1.4 due to output volatility and 7.3 due to inflation volatility. Most of the loss is due to inflation, because as we have seen in the figure 10, inflation is much more volatile than output following TFP shocks.

We can now try to find a monetary rule such that the loss function is minimized, *i.e.* find what is the best action for the central bank to minimize the volatility following TFP shocks. We keep the same framework as above, so that the rule is about money creation, not about interest rate, and we focus on helicopter money rather than on quantitative easing (as we have seen, the aggregate responses for inflation and output are similar for both policies). The idea is to see if, when the inflation or output are too far away for the target, the central bank can increase or decrease the money in circulation to get closer to the target. Then, we replace the simple "passive" rule $\frac{M_t - M_{t-1}}{M_{t-1}} = (1 - \phi_m)(\bar{\pi} - 1) + \phi_m \frac{M_{t-1} - M_{t-2}}{M_{t-2}} + \varepsilon_t^M$ used in the experiments in previous part, by a more "active rule" of the following form:

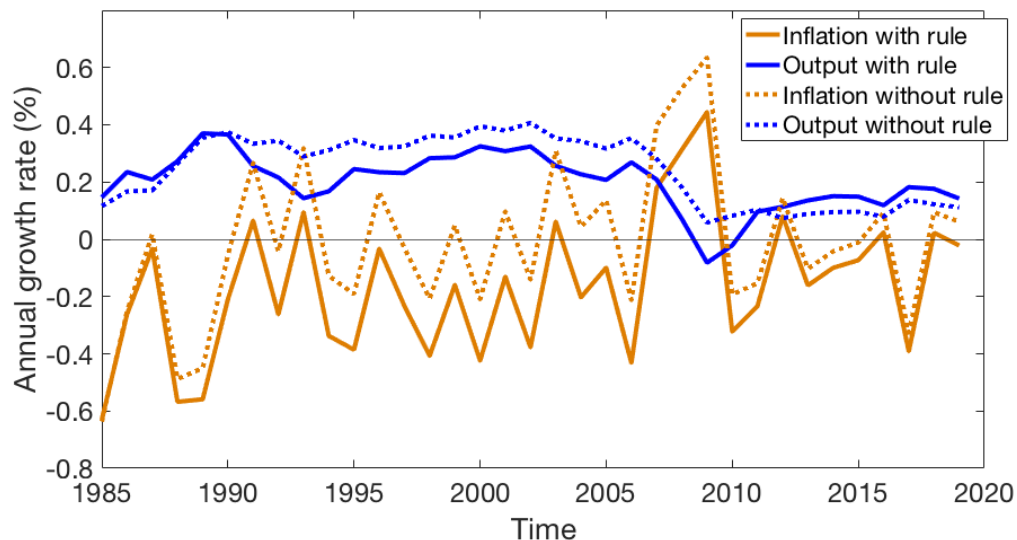
$$\frac{M_t - M_{t-1}}{M_{t-1}} = (\bar{\pi} - 1) - \sigma_Y \widehat{Y}_t - \sigma_\pi \widehat{\pi}_t + \varepsilon_t^M$$

This rule has two parts. The first one is common to the previous rule, saying that the money growth at the equilibrium is equal to the inflation target. The second part implies that money growth reacts to changes in output and inflation compared to targets, depending on the respective parameters σ_Y and σ_π . The minus signs are used to have σ_Y and σ_π positive: indeed, when inflation or output are below the target (resp. above), the central bank should increase (resp. decrease) the amount of money (since helicopter money increases inflation and output), so that there is a negative correlation between \widehat{Y}_t or $\widehat{\pi}_t$ and the money growth, reflected by the minus signs. We now adopt the following strategy to compute the optimal monetary rule:

- Create a grid for σ_Y and σ_π ;
- Simulate for each couple (σ_Y, σ_π) (*i.e.*, for each possible monetary policy rule) the output and inflation paths following TFP shocks between 1985 and 2019
- Compute for each couple the loss function

Then, we select the couple (σ_Y, σ_π) that minimizes the loss for the central bank: we find that (3,4) is the optimal monetary policy. This means that to stabilize output and inflation, the central bank should put a higher weight on the inflation gap than on the output gap, which reflects the fact that inflation is more volatile than output. With this rule, the loss would have been smaller for the central bank, and equal to $\mathbb{L} = 7$, with 1 due to output volatility and 6 due to inflation volatility (instead of respectively 8.7, 1.4 and 7.3 with the previous rule). By increasing money creation during recessions caused by TFP shocks, and by reducing money base when output or inflation is too high, this rule enables to smooth fluctuations and to reduce volatility by 16% (from 8.7 to 7). We plot on the following graph what could have been the output and inflation paths between 1985 and 2019 with this rule, and we compare it with the paths without the rule.

Figure 11: Annual growth rate of inflation and output in our model



The reduction of volatility is not very visible in this graph: the solid lines do not seem to be less volatile than dotted lines. In fact, even if 16% is a sizable reduction of volatility, we cannot hope to achieve a much better level of business cycle smoothing in this model. The reason is simple: here, we consider only shocks related to TFP, and as we explained before, output and inflation are negatively correlated following TFP shocks, so that when inflation is above the target, output is below and reciprocally. At the opposite, since output and inflation are positively correlated following monetary shock (QE or helicopter), we cannot stabilize both at the same time: following a very negative productivity shock, inflation increases and output decreases, and if we try to create money to increase output, inflation will increase even more, so that what we gain from one side is lost on the other. Then, facing TFP shocks, money creation may not be very efficient to stabilize volatility: maybe a rule on interest rate is more adapted. However, this inefficiency of helicopter money to stabilize both output and inflation is true only for TFP shocks: if we had other shocks in our model, such that the correlation between inflation and output would be positive, we could achieve a reasonable stabilization with our unconventional monetary policy.

7 Conclusion

The Covid-19 crisis has highlighted the increasingly complex dilemma faced by central banks and governments since 2008: the need to increase public expenditure and to stimulate the economic activity, with less room for maneuver for monetary policy due to the zero lower bound on interest rates, and for fiscal policy due to the very high level of public debt. In this situation, the European Central Bank has renewed its support for the economy, by increasing the size of its asset purchase program. This unconventional monetary policy, the quantitative easing, started in 2009 and has constantly been increased since then, with sizable effects on inflation and output. By replacing illiquid assets (public debt in our model) by liquid wealth (money), it increases consumption, demand, output and inflation. However, this policy has been criticized for its effectiveness and its impact on inequalities. Indeed, quantitative easing targets agents who hold assets: they may be wealthier than average, and then have a smaller marginal propensity to consume. Then, this paper investigates another way of allocating the money created: transferring money to all households equally, that is to say helicopter money.

Building on the contribution of Gali (2020) for the money creation part, Cui and Sterk (2019) for the QE analysis and Bilbiie, Monacelli and Perotti (2013) for the heterogeneity, we create a Two-Agent New Keynesian (TANK) model, to evaluate the effect of QE and compare it with the effect of helicopter money. We find that QE and helicopter money are efficient to increase output, consumption and inflation: the effects are a bit higher for helicopter money, because it targets all households, whereas QE targets agents with a smaller marginal propensity to consume. However, these two policies differ for disaggregate variables: QE is biased towards Ricardian agents and increase their consumption more than the Keynesian one, whereas helicopter money benefits more to Keynesian households and decreases slightly the Ricardian consumption.

We also investigate the effects of the quantitative easing program implemented by the ECB since 2009, and find that it contributed to sizable increase in inflation and consumption. However, in the same period, we also compute that helicopter money would have been more efficient, while reducing inequalities instead of

increasing it. We conduct a welfare analysis for both policies, and show that for Ricardian households, QE is better than helicopter but the magnitude of the welfare gains or losses are very small, whereas for Keynesian households, both policies yield sizable gain, but twice higher with helicopter policy than with QE. Finally, we analyse the effects of TFP shocks in our model: a positive productivity shock increases output but reduces inflation, so that even the optimal monetary policy cannot achieve a high level of stabilization, because helicopter money and QE increase both output and inflation.

This paper contributes to the literature on unconventional monetary policy, by highlighting one potential drawback of the quantitative easing program: the increase in inequality and the loss of efficiency. It has serious shortcomings that should be investigated in further research: the heterogeneity is introduced in its simplest form and should be developed, the financial markets are almost nonexistent while the quantitative easing intervenes directly on them, and the interest rate is not constrained by a zero lower bound. Due to these imperfections, and the theoretical nature of the model used, it does not represent a manifesto for helicopter money, money creation or debt monetization, but rather a reflection on the efficiency of quantitative easing, and a way to lift the taboo on money creation: in these times of economic crises and growing uncertainty, maybe unconventional tool may help to solve unconventional problems.

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Appendix

Robustness

Figure A1: IRFs for different values of χ

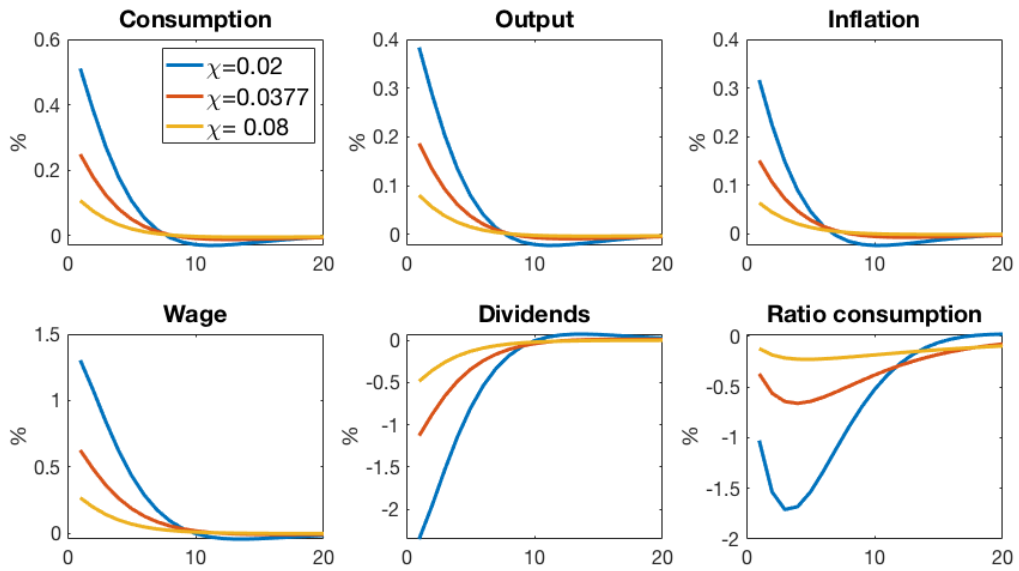


Figure A2: IRFs for different values of ϕ_M

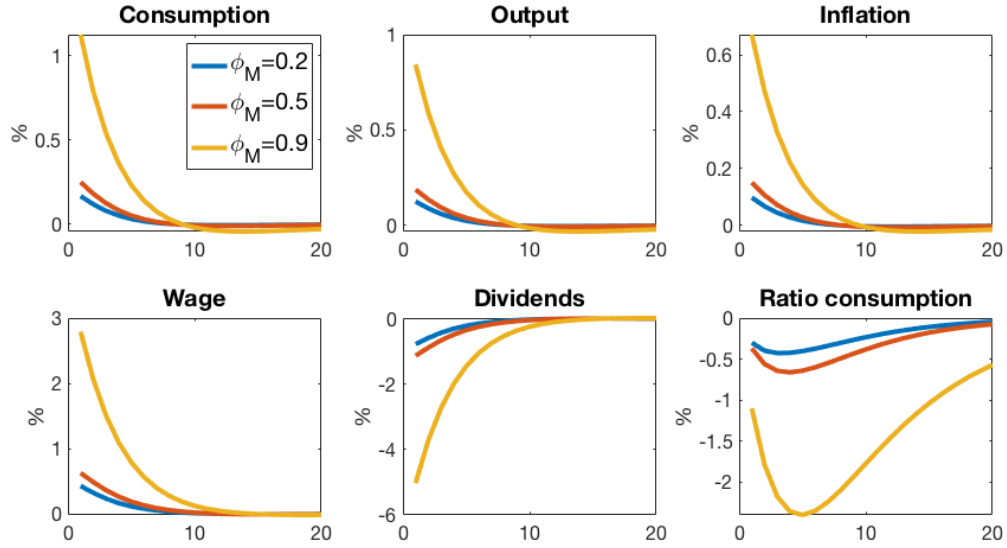
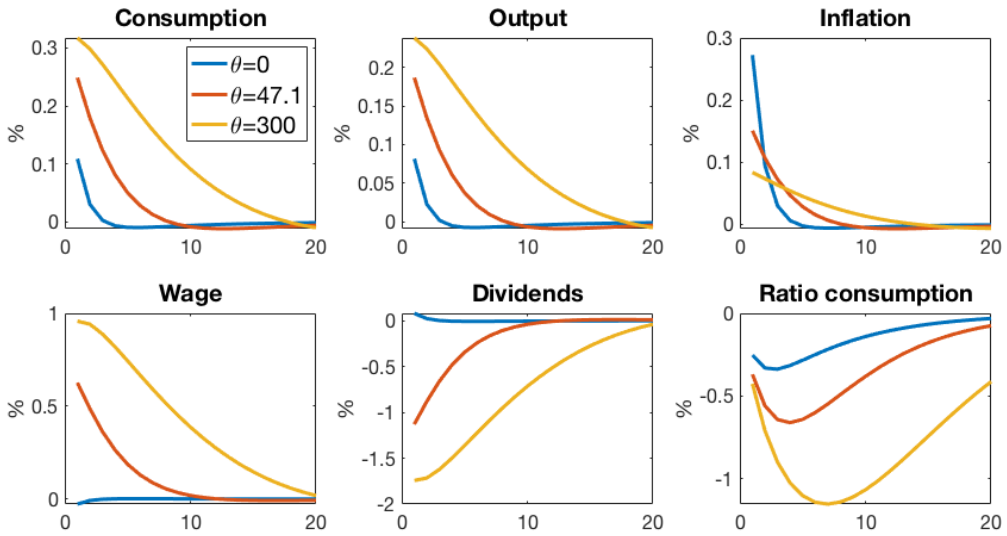


Figure A3: IRFs for different values of θ



Increase in public expenditure

Figure A4: IRFs for a money-financed increase in public spending

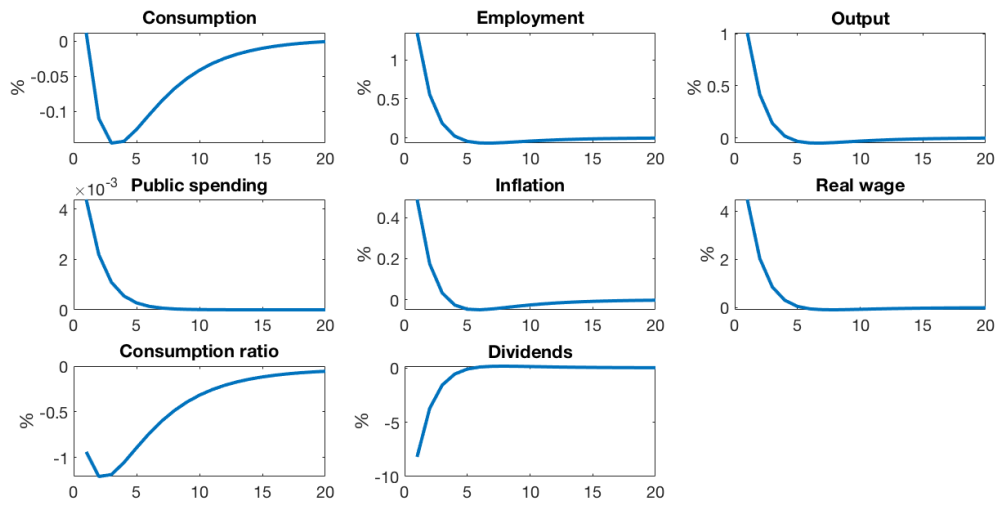


Figure 1: Responses after a money creation shock equal to 1% of steady state output and transferred to government to increase public spending.