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Modern Macroeconomics and Heterogeneity

Macroeconomia Moderna e a Heterogeneidade

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ABSTRACT
Modern macroeconomics has evolved from focusing just on the dynamics of aggregates, such as income, consumption and savings, to the dynamics of the distributions that add up to those aggregates. This is a consequence of theoretical contributions and increasing data availability and computational power. Though contributions regarding heterogeneity in macroeconomics can be traced back to the first half of the 20th century, it is only by the 2010s that we evolved towards a framework where there is a rich interaction between macroeconomic aggregates and their distributions that goes both ways. This special edition focused on contributions that build on such framework to study open questions regarding the impact of fiscal shocks on output, the impact of investment-specific technological change on inequality, optimal tax structures, and the impact of the COVID-19 pandemic on the distribution of earnings.
Keywords: Macroeconomics; heterogeneity; fiscal policy; optimal taxation; inequality; COVID-19 pandemic.

JEL Classification: E62; E21; E13; E17.

RESUMO
A macroeconomia moderna evoluiu do foco apenas na dinâmica dos agregados, como rendimento, consumo e poupança, para a dinâmica das distribuições que constituem esses agregados. Isto é consequência de contribuições teóricas e do aumento da disponibilidade de dados e do poder computacional. Embora as contribuições relativas à heterogeneidade na macroeconomia possam ser encontradas desde a primeira metade do século XX, foi apenas na década de 2010 que se evoluiu para um quadro onde há uma rica interação entre agregados macroeconómicos e suas distribuições que se exprime nos dois sentidos. Esta edição especial é constituída por contribuições que se baseiam neste quadro conceptual e visam estudar questões em aberto sobre o impacto dos choques orçamentais sobre o produto, o impacto do progresso tecnológico dos bens de investimento na desigualdade, as estruturas fiscais ótimas e o impacto da pandemia COVID-19 na distribuição de rendimentos.

Palavras-chave: Macroeconomia; heterogeneidade; política orçamental; taxação ótima; desigualdade; pandemia da COVID-19.

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1. Introduction

Modern macroeconomics has expanded its focus from the study of aggregate variables such as income, consumption and wealth, to the dynamics of distributions of these variables (see Krueger et al. (2010)). Advances in computational methods and hardware and the greater availability of microdata has provided researchers not only the means to build, solve and simulate models that account in greater detail for characteristics that differ across agents (be it households, firms or other), but also the data do discipline them.

Rather than a revolution, seldom observed in the field of economics, the relevance of heterogeneous agent models has been growing in importance, in a slow but steady pace (see Cherrier (2018)). The most recent methodological contributions in macroeconomics have focused mainly on this, in particular on solution methods to heterogeneous agents new Keynesian (HANK) models.

The growth in importance of this class of models can only be partially justified by the greater availability of microdata and more powerful computational methods and hardware. This only tells the supply side of the story. There is also a demand side. First by the society at large. Macroeconomists have often been criticized by relying too much on the representative agent framework, (see Chancellor, 2017, for example), even if sometimes those critiques often depict the state of the art in macroeconomics research 20 or even 30 years before, as in the given example. Second, by the profession in itself. Following the words of Deaton (2016), *"While we often must focus on aggregates for macroeconomic policy, it is impossible to think coherently about national well-being while ignoring inequality and poverty, neither of which is visible in aggregate data"*, some questions cannot be properly addressed in representative agent frameworks. But Deaton (2016) goes beyond that and also claims that *"Indeed, and except in exceptional cases, macroeconomic aggregates themselves depend on distribution*".

This line of research has come a long way. Early work by Kaldor (1955) and Pasinetti (1962) focused on the distributional implications of economies with two types of agents, capitalists and workers. In this framework, agents are *ex-ante* different, and as such, heterogeneity is exogenous. In a similar fashion, models where agents feature life-cycle behavior started to be explored. Following Aliprantis, Brown, and Burkinshaw (1990), macroeconomic models where agents of different ages coexist, owes its intellectual origins to the works of Irvin Fischer (see Fisher (1930)). This inspired the work by Maurice Allais (see Malinvaud (1987)) and Samuelson (1958)), with the latter often considered the seminal paper given its rigorous formulation and characterization of an overlapping generations model. Later, Diamond (1965) introduced a neoclassical aggregate production function with two purposes, namely to examine the long-run competitive equilibrium in a growth model and then to explore the effects on this equilibrium, of government debt. It is also in this paper that Diamond shows that despite the absence of all the usual sources that can lead to inefficiency, the competitive solution can be inefficient.

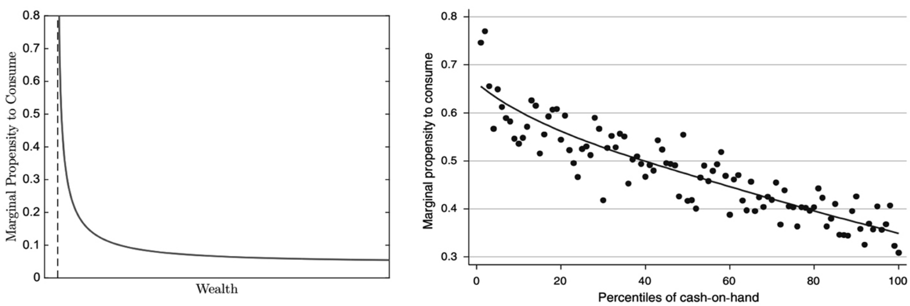
Despite the fact that age as a dimension of micro-heterogeneity preceded incomplete markets in being explored in macroeconomic models, contemporaneously the term heterogeneous agents model is typically used to refer to models of incomplete markets. These models feature uninsurable idiosyncratic risk and may include other sources of market incompleteness such as potentially binding credit constraints. The seminal reference in this class of models is Bewley (1980) who revisits the permanent income hypothesis in a stochastic endowment economy and no state-contingent bonds through which agents could insure against their idiosyncratic risk. Imrohoroğlu (1989) disputes the results in the classical paper on welfare costs of business cycles by Lucas (see Lucas (1987)) by studying an environment with indivisibilities and liquidity constraints. Huggett (1993) looks at precautionary behavior as an explanation of why the risk free interest rate in representative agent models was higher than what was observed in the data. Later Aiyagari (1994) showed that the aggregate implications of such channel are likely to be small. This paper was the first to provide a general equilibrium model with uninsurable idiosyncratic risk and borrowing constraints and remains the main reference for what is commonly referred to as the standard incomplete markets (SIM) model.

The next big methodological leap in the modeling of incomplete markets came with Krusell and Smith (1998) who provide an algorithm to solve models that feature both uninsurable idiosyncratic shocks and aggregate risk. In principle, the problem is infinitely dimensional, because the whole distribution of wealth in the economy becomes a state variable, and this is an infinite dimension object. In practice, however, Krusell and Smith (1998) show that using only one moment of the whole distribution – *average wealth* – sufficed to solve the model to a very high degree of accuracy. Of particular importance for some of the discussion ahead, Krusell and Smith (1998) use heterogeneity in discount factors to generate an empirically plausible wealth distribution. A few years later, Castaneda, Diaz-Gimenez, and Rios-Rull (2003) use the SIM model to also account for income and wealth inequality in the U.S. without resorting to heterogeneity in discount factors, but instead by estimating, within the model, income processes that generate moments of the observed distribution on wealth and income.

This first generation of incomplete market models provided macroeconomists with the methodological tools to study the distributional impacts of events at the macro level but the implications of micro-heterogeneity for the macro aggregates were just not quantitatively relevant. First, as mentioned above, despite the point that Huggett (1993) made regarding the role of precautionary behavior in response to uninsurable risk and its potential implications for the risk free rate, the macro impacts were found to be very small by Aiyagari (1994). Second, and most importantly, the results by Krusell and Smith (1998) – the fact that average capital, as opposed to the whole distribution of capital was enough to solve for the model – seemed to suggest that the micro-heterogeneity simply was not that relevant for aggregate dynamics. In fact, Lucas (2003) went as far as to say that *"For determining the behavior of aggregates, they* [Krusell and Smith (1998)] *discovered, realistically modeled household heterogeneity just does not matter very much"*.

One of the key reasons why this generation of models did not generate meaningful impacts from micro-heterogeneity into aggregate dynamics, had to deal with the fact that, though typically the models could account for the distribution of wealth and income and even other dimensions, it failed in accounting for the distribution of marginal propensities to consume (and to work), as Moll (2017) shows in the Figure 1 below, using data from Jappelli and Pistaferri (2014) on self- reported marginal propensities to consume.

Figure 1: Marginal Propensities to consume in a standard Aiyagari (1994) model and data



So far, the use of these models had been mostly to study the dynamics of real variables and their respective distributions. One would have to wait until Oh and Reis (2012) for the first general equilibrium incomplete markets model with nominal rigidities. The paper focused on the fiscal response to the Great Recession that, the authors show, was predominantly through the increase in government transfers. With this environment, the authors show that targeted lump-sum transfers are expansionary both because of a neoclassical wealth effect and because of a Keynesian aggregate demand effect. The first model with nominal rigidities and both aggregate and idiosyncratic risk was featured in McKay and Reis (2016), who use it to study the role of automatic stabilizers in the U.S. business cycle. This was, in effect, the first HANK model, despite the term being popularized only later by Kaplan, Moll, and Violante (2018). This new generation of models was praised by policy makers (see Yellen (2016) and Constâncio (2017) for example) as they provided a much greater role for micro-heterogeneity to have an impact on aggregate variables than the previous one. A key feature for this was precisely an addition of a number of extensions (such as illiquid assets as in Kaplan and Violante (2014)) that improved the empirical plausibility of marginal propensities to consume in this class of models and thus gave a much larger role to the micro-heterogeneity.

2. **Model Features**

In the series of essays that make this special issue, the baseline model is the one I have used with my co-authors in a series of papers, starting with Brinca et al. (2016), with some changes depending on the research question being asked. The main differences in the subsequent papers can be found in alternative wage processes, as well as alterning production technologies. In this section, I will start outlying the general model features, commenting on the rationale behind each part, and introduce the different specifications the following papers use. The mechanism that served as motivation for Brinca et al. (2016) is not an original contribution in itself. The point we wanted to make was that, using an unrealistic though stylized fiscal policy experiment in the literature a balanced-budget increase in government expenditures financed by a lumpsum tax, observable cross-country differences in the wealth distribution can lead to economically meaningful differences in fiscal multipliers. Following Heathcote (2005), the Ricardian insight, revisited by Barro (1974), is that if capital markets are perfect, taxes are lump-sum and households dynastic, the timing of taxes does not matter for households' consumption decisions. Hence, in a dynastic representative agent framework, differences in wealth distributions would not, by assumption, produce any difference in terms of fiscal multipliers, since Ricardian Equivalence would hold. However, we do know (as did Ricardo), that not only capital markets are not perfect, people also do live finite lives. So, if out to study the role of the wealth distribution in the response of the economy to fiscal policy shocks, one needs to take these features into account, both methodologically and for the sake of empirical relevance, as the literature seems to agree that budget deficits have non-negligible effects on both consumption and interest rates. This is a key motivation behind Brinca et al. (2016). Not the mechanism in itself   the breaking of Ricardian Equivalence due to market incompleteness, something we know for a long time but its quantitative relevance, in particular in face of other relevant dimensions along which different economies also differ, be it social security systems, tax structures, etc.

Demographics

The economy is populated by overlapping generations of finitely lived households. The choice of an overlapping generations (OLG) structure is twofold. Recent work by Peterman and Sager (2016) makes the case for having a life-cycle dimension when studying the impacts of government debt. All households start life at age 20 and enter retirement at age 65. Let j denote the household's age. Retired households face an age-dependent probability of dying, $\pi(j)$ and die for certain at age 100.[1] A model period is 1 year, so there are a total of 45 model periods of active work life. We assume that the size of the population is fixed (there is no population growth). We normalize the size of each new cohort to 1. Using $\omega(j)=1-\pi(j)$ to denote the age-dependent survival probability, by the law of large numbers the mass of retired agents of age $j \geq 65$ still alive at any given period is equal to $\boldsymbol{\Omega} = \prod_{q=65}^{q=j-1} \omega(q)$. There are no annuity markets, so that a fraction of households leave unintended bequests, which are redistributed in a lump-sum manner between the households that are currently alive. We use to denote the per-household bequest. Retired households' utility is increasing in the bequest they leave when they die. This helps us calibrate the asset holdings of old households.

Preferences

The momentary utility function of a household, $U(c,n)$, depends on consumption and work hours, $n \in (0,1)$, and takes the following form:

$$U(c,n) = \frac{c^{1-\sigma}}{1-\sigma} - \chi \frac{n^{1+\eta}}{1+\eta}$$

[1] This means that $J = 81$.

where σ and η pin down the coefficient of relative risk aversion and the Frisch elasticity, and χ scales the disutility of hours worked which helps us to match the average hours worked in the economy. In order to make the age profile of wealth empirically plausible, in Brinca, H. Ferreira, et al. (2019) we made it such households gain utility from the bequest they leave when they die, again scaled by φ:

$$D(k) = \varphi \log(k)$$

Note also that we allow for agents to have different time preference parameters β. As it will be clear in the calibration section of each of the applications, the number of different time preference parameters will be chosen by the number of moments in the wealth distribution that targeted.

Government

The government runs a balanced social security system where it taxes employees and the employer (the representative firm) at rates τ_{ss} and $\tilde{\tau}_{ss}$ and pays benefits, Ψ_t, to retirees. The government also taxes consumption and labor and capital income to finance the expenditures on pure public consumption goods, G_t, which enter separably in the utility function, interest payments on the national debt, rB_t, and a lump-sum redistribution, g_t. We assume that there is some outstanding government debt and that government debt-to-output ratio, $B_y = B_t / Y_t$, does not change over time in the stochastic steady state. Consumption and capital income are taxed at flat rates the τ_c and τ_k. To model the non-linear labor income tax, we use the functional form proposed in Benabou (2002) and recently used in Heathcote, Storesletten, and Violante (2017) and Holter, Krueger, and Stepanchuk (2017):

$$\tau_l(y) = 1 - \theta_0 y^{-\theta_1}$$

where y denotes pre-tax (labor) income and $\tau_l(y)$ the average tax rate given a pre-tax income of y. The parameters θ_0 and θ_1 govern the level and the progressivity of the tax code, respectively. Heathcote, Storesletten, and Violante (2017) argue that this function fits the U.S. data well.

In a steady state, the ratio of government revenues to output will remain constant. G_t, g_t, and Ψ_t must also remain proportional to output. Denoting the government's revenues from labor, capital, and consumption taxes by R_t and the government's revenues from social security taxes by R_t^{ss}, the government budget constraint in steady state takes the following form:

$$g\Big(45 + \sum_{j \geq 65} \Omega_j\Big) = R - G - rB$$
$$\Psi\Big(\sum_{j \geq 65} \Omega_j\Big) = R^{ss}$$

Labor Income

The wage of an individual depends on his/her own characteristics: age, j, permanent ability, $a \sim N(0, \sigma_a^2)$, and idiosyncratic productivity shock, u, which follows an AR(1) process:

$$u_{t+1} = \rho u_t + \epsilon_{t+1}, \qquad \epsilon \sim N(0, \sigma_\varepsilon^2)$$

These characteristics will dictate the number of efficient units of labor the household is endowed with. Individual wages will also depend on the wage per efficiency unit of labor w. Thus, individual 's wage is given by:

$$w_i(j,a,u) = we^{y_1 j + y_2 j^2 + y_3 j^3 + a + u}$$

y_1, y_2 and y_3 capture the age profile of wages. The wage w is determined by the first order condition specified in the technology section below.

Technology

The following papers use two distinct production functions. On the following we will illustrate the two distinct environments and call them model 1 and model 2 respectively. The last paper in this collection uses a variation of model 2, which will be explained in the respective paper, in detail.

Model 1

There is a representative firm, producing output with a Cobb-Douglas production function:

$$Y_t(K_t, L_t) = K_t^\alpha L_t^{1-\alpha}$$

where is the capital input and the labor input in efficiency units. The evolution of capital is given by:

$$K_{t+1} = (1 - \delta)\, K_t + I_t$$

where is gross investment and the capital depreciation rate. Each period, the firm hires labor and capital to maximize its profits:

$$\Pi_t = Y_t - w_t L_t - (r_t + \delta) K_t.$$

In a competitive equilibrium, the factor prices will be equal to their marginal products given by:

$$w_t = \partial Y_t / \partial L_t = (1 - \alpha)\left(\frac{K_t}{L_t}\right)^\alpha$$

$$r_t = \partial Y_t / \partial K_t - \delta = \alpha \left(\frac{L_t}{K_t} \right)^{1-\alpha} - \delta$$

Consequently, the wage rate in (7) will be determined by the first order condition (11).

Model 2

The second model differs from the one presented above in the production function employed. The economy still behaves in perfect competition, however a constant elasticity of substitution (CES) production function gathers the input capital (K), skilled (L_t^S) and unskilled labor (L_t^{NS}) to produce the final output Y_t. The factor Z_t describes an intermediate good which can be produced using either capital and skilled labor. The final output then combines the composite Z_t with unskilled labor to the final output as follows:

$$Y_t = F(A_t, N_t^{NS}, N_t^S) A_t (\phi_1 Z_t^{\frac{\sigma-1}{\sigma}} + (1-\phi_1) N_t^{NS, \frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}}$$

$$Z_t = (\phi_2 A_{k,t} K_t^{\frac{\rho-1}{\rho}} + (1-\phi_2) N_t^{S, \frac{\rho-1}{\rho}})^{\frac{\rho}{\rho-1}}$$

A_t refers to the technology level, $A_{k,t}$ refers to capital augmented technological level, ϕ_1 describes the share of the intermediate factor, ϕ_2 the share of capital within the intermediate factor, whereas ρ is the elasticity of substitution between capital and skilled labor and σ is the elasticity of substitution between composite factors and unskilled labor. This nested production function is similar to (Karabarbounis and Neiman 2013) and (Krusell et al. 2000) with capital and skilled labor acting as complements, whereas unskilled labor is a substitute with respect to the composite intermediate factor. As in the model 1, capital evolves according to the equation:

$$K_{t+1} = (1-\delta) K_t + I_t$$

Finally, perfect competition implies that in competitive equilibrium factor prices equal the marginal products:

$$r_t = \frac{\partial Y_t}{\partial K_t} - \delta = \left[A_t^{\sigma-1} Y_t \right]^{\frac{1}{\sigma}} \phi 1 Z_t^{\frac{\sigma-\rho}{\sigma\rho}} \phi_2 \left(\frac{1}{Kt} \right)^{\frac{1}{\rho}} - \delta$$

$$W_t^S = \frac{\partial Y_t}{\partial N_t^S} = \left[A^{\sigma-1} Y_t \right]^{\frac{1}{\sigma}} \phi_1 Z_t^{\frac{\sigma-\rho}{\sigma\rho}} (1-\phi_2) \left(\frac{1}{N_t^S} \right)^{\frac{1}{\rho}}$$

$$W_t^{NS} = \frac{\partial Y_t}{\partial N_t^{NS}} = (1-\phi_1) \left(\frac{A_t^{\sigma-1} Y_t}{N_t^{NS}} \right)^{\frac{1}{\sigma}}$$

In contrast to model 1, now there are two different wage rates. Depending on the individual providing skilled or unskilled labor the wage in equation (8) is substituted through the expression (17) and (18).

Recursive Formulation of the Household Problem

At any given time a household is characterized by (k, β, a, u, j), where k is the household's savings, β is the time discount factor that randomly takes up to four different lifetime values, a is permanent ability, u is the idiosyncratic productivity shock, and j is the age of the household. In the case of model 2, households furthermore are differentiated by their different skill level $s \in \{NS, S\}$ refering to non-skilled labor, and skilled labor. We can formulate the household's optimization problem over consumption, c, work hours, n, and future asset holdings, k', recursively as follows:

$$V(k, \beta, a, u, j) = \max_{c,k',n}[U(c, n) + \beta E_{u'} V(k', \beta, a, u, j + 1)]$$

s.t.

$$c(1 + \tau_c) + k' = (k + \Gamma)(1 + r(1 - \tau_k)) + g + Y^L$$

$$Y^L = \frac{nw(j, a, u)}{1 + \tilde{\tau}_{ss}}\left(1 - \tau_{ss} - \tau_l\left(\frac{nw(j, a, u)}{1 + \tilde{\tau}_{ss}}\right)\right)$$

$$n \in [0,1],\ k' \geq -b,\ c > 0$$

Here, Y^L is the household's labor income after social security taxes and labor income taxes. τ_{ss} and $\tilde{\tau}_{ss}$ are the social-security contributions paid by the employee and by the employer, respectively. The problem of a retired household, who has a probability $\pi(j)$ of dying and gains utility $D(k')$ from leaving a bequest, is:

$$V(k, \beta, j) = \max_{c,k'}[U(c, n) + \beta(1 - \pi(j))V(k', \beta, j + 1) + \pi(j))D(k')]$$

s.t.

$$c(1 + \tau_c) + k' = (k + \Gamma)(1 + r(1 - \tau_k)) + g + \Psi$$

$$k' \geq 0,\ c > 0$$

For model 2 we can formulate the recursive problem once for the skilled and the non-skilled individuals, both facing their respective factor prices. Besides this, the recursive formulation illustrated above remains unchanged.

Stationary Recursive Competitive Equilibrium

Let the measure of households with the corresponding characteristics be given by $\Phi(k, \beta, a, u, j)$. The stationary recursive competitive equilibrium is defined by:

Given the factor prices and the initial conditions the consumers' optimization problem is solved by the value function $V(k, \beta, a, u, j)$ and the policy functions, $c(k, \beta, a, u, j)$, $k'(k, \beta, a, u, j)$, and $n(k, \beta, a, u, j)$.

Markets clear:

$$K + B = \int k d\phi$$
$$L = \int \left(n\left(k, \beta, a, u, j\right)\right) d\phi$$
$$\int c d\phi + \delta K + G = K^{\alpha} L^{1-\alpha}$$

Whereas in model 2 there are two labor equilibrium conditions for skilled and non-skilled labor that need to be satisfied.

The factor prices satisfy either:

$$w = (1-\alpha)\left(\frac{K}{L}\right)^{\alpha}$$
$$r = \alpha\left(\frac{K}{L}\right)^{\alpha-1} - \delta$$

in model 1 or in model 2:

$$r_t = \left[A_t^{\sigma-1} Y_t\right]^{\frac{1}{\sigma}} \phi_1 Z_t^{\frac{\sigma-\rho}{\sigma\rho}} \phi_2 \left(\frac{1}{K_t}\right)^{\frac{1}{\rho}} - \delta$$
$$w_t^S = \left[A_t^{\sigma-1} Y_t\right]^{\frac{1}{\sigma}} \phi_1 Z_t^{\frac{\sigma-\rho}{\sigma\rho}} (1-\phi_2) \left(\frac{1}{N_t^S}\right)^{\frac{1}{\rho}}$$
$$w_t^{NS} = (1-\phi_1)\left(\frac{A_t^{\sigma-1} Y_t}{N_t^{NS}}\right)^{\frac{1}{\sigma}}$$

The government budget balances:

$$g \int d\phi + G + rB = \int \left(\tau_k r\left(k + \Gamma\right) + \tau_c c + n\tau_l \left(\frac{nw\left(a,\ u,\ j\right)}{1 + \tilde{\tau}_{ss}}\right)\right) d\phi$$

The social security system balances:

$$\Psi \int_{j \geq 65} d\phi = \frac{\tilde{\tau}_{ss} + \tau_{ss}}{1 + \tilde{\tau}_{ss}} \left(\int_{j < 65} nwd\phi \right)$$

The assets of the dead are uniformly distributed among the living:

$$\Gamma \int \omega(j)\, d\phi = \int (1 - \omega(j))\, kd\phi$$

3. Applications

In this section I describe the seven essays that follow as well as any departures from the baseline model that were needed. The first three focus on fiscal multipliers, namely the relationship between fiscal multipliers and labor tax progressivity; the relationship between the speed of consolidation programs and welfare; and the importance of asset liquidity for the fiscal policy transmission mechanism. In all three essays, the experiments are similar to the ones we did in Brinca et al. (2016), Brinca, Ferreira, et al. (2019) and Brinca, Faria-e--Castro, et al. (2019). The transmission mechanism hinges fundamentally on the aggregate response of labor supply to the fiscal shock. Since credit constrained agents behave like hand-to-mouth agents, their labor supply elasticity w.r.t. to income shocks, present and/or future, is different from wealthier agents whose consumption and leisure behavior will respond directly to changes in permanent income. Hence, the share of each type of agents in the economy will be a key factor driving the magnitude of the output response to the fiscal shock.

The second four applications are focused on the impacts of investment-specific technological change on inequality, and optimal tax structures. In this case, the production structure of the economy needs to be augmented to include different types of capital and labor inputs and technological processes. In particular the inclusion of technical change that will change the relative demand of distinct labor inputs according to their different degrees of substitutability/complementarity with capital. This setup is inspired by our work in Brinca et al. (2019). Here, the key insight is that optimal tax structures depend crucially on the degree to which income inequality arises from differences in uninsurable shocks versus permanent differences between individuals from the start (see Heathcote, Storesletten, and Violante (2017)), and that investment specific technological change, to the degree that the majority of workers does not change the type of occupation they perform during their life-course, has an impact on the permanent differences between individuals.

References

Aiyagari, S. R. (1994) Uninsured idiosyncratic risk and aggregate saving. *Quarterly Journal of Economics, 109*(3), 659-684.

Aliprantis, C. D.; Brown, D. J.; Burkinshaw, O (1990) The Overlapping Generations model. In Existence and Optimality of Competitive Equilibria. Springer Berlin Heidelberg, 229-271.

Barro, R. (1974) Are government bonds net wealth? *Journal of Political Economy, 82*(6), 1095-1117.

Bernabou, R. (2002) Tax and education policy in a heterogeneous agent economy: what levels of redistribution maximize growth and efficiency? *Econometrica, 70*(2), 481-517.

Bewley, T. (1980) The Permanent income hypothesis and long-run economic stability. *Journal of Economic Theory, 22*(3), 377-394.

Brinca, P.; Duarte, J. B.; Holter, H. A.; Oliveira, J. G. (2019) *Investment-Specific Technological Change, Taxation and Inequality in the U.S.*, Germany, MPRA Paper 91463, University Library of Munich.

Brinca, P.; Faria-e-Castro, M.; Ferreira, M. H.; Holter, H. (2019) *The Nonlinear Effects of Fiscal Policy*, FRB St. Louis Working Paper 2019-15.

Brinca, P.; Ferreira, M. H.; Franco, F. A.; Holter, H. A.; Malafry, L. (2019) Fiscal Consolidation Programs and Income Inequality, Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3071357, Available at SSRN 3071357.

Brinca, P.; Holter, H. A.; Krusell, P.; Malafry, L. (2016) Fiscal multipliers in the 21st century. *Journal of Monetary Economics 77*, 53-69.

Castaneda, A.; Diaz-Gimenez, J.; Rios-Rull, J. (2003) Accounting for the U.S. earnings and wealth inequality. *Journal of Political Economy*, *111*(4), 818-857.

Chancellor, E. (2017). Review: Can We Avoid Another Financial Crisis? REUTERS. Retrieved from https://www.reuters.com/article/us-review-crisis-breakingviews-idUSKBN1811XP

Cherrier, B. (2018). Heterogeneous agents macroeconomics has a long history, and it raises many questions. the undercover historian. Retrieved from https://beatricecherrier.wordpress.com/2018/11/28/heterogeneous-agent-macroeconomics-has-a-long-history-and-it-raises-many-questions/.

Constâncio, V. (2017) Inequality and Macroeconomic Policies. Intervention by Vítor Constâncio, Vice-President of the ECB, at the Annual Congress of the European Economic Association Lisbon, 22 August. Retrieved from https://www.ecb.europa.eu/press/key/date/2017/html/ecb.sp170822.en.html.

Deaton, A. (2016) Measuring and understanding behavior, welfare, and poverty. *American Economic Review*, *106*(6),1221-1243.

Diamond, P. A. (1965) National debt in a neoclassical growth model. *American Economic Review, 55*(5), 1126-1250.

Fisher, I. (1930) The theory of interest as determined by impatience to spend income and opportunity to invest it. *Bull. Amer. Math. Soc, 36*, 783-784.

Heathcote, J. (2005) Fiscal policy with heterogeneous agents and incomplete markets. *Review of Economic Studies 72*(1), 161-188.

Heathcote, J.; Storesletten, S.; Violante, G. L. (2017) Optimal tax progressivity: an analytical framework. *Quarterly Journal of Economics, 132*(4), 1693-1754.

Heathcote, J.; Storesletten, K.; Violante, G. L. (2020) How should tax progressivity respond to rising income inequality? *Journal of the European Economic Association*. Available at https://doi.org/10.1093/jeea/jvaa050

Holter, H. A.; Krueger, D.; Stepanchuk, S. (2019) How do tax progressivity and household heterogeneity affect Laffer curves? *Quantitative Economics*, 10(4), 1317-1356.

Huggett, M. (1993) The risk-free rate in heterogeneous-agent incomplete-insurance economies. *Journal of Economic Dynamics and Control 17*(5-6), 953-969.

Imrohoroğlu, A. (1989) Cost of Business cycles with indivisibilities and liquidity constraints. *Journal of Political Economy, 97*(6), 1364-1383.

Jappelli, T.; Pistaferri, L. (2014) Fiscal policy and MPC heterogeneity. *American Economic Journal: Macroeconomics 6*(4), 107-136.

Kaldor, N. (1955) Alternative theories of distribution. *Review of Economic Studies 23*(2), 83-100.

Kaplan, G., Moll, B.; Violante L. G. (2018) Monetary Policy according to Hank. *American Economic Review, 108*(3), 697-743.

Kaplan, G.; Violante L. G. (2014) A model of the consumption response to fiscal stimulus payments. *Econometrica, 82*(4), 1199-11239.

Karabarbounis, L.; Neiman, B. (2013) The global decline of the labor share. *Quarterly Journal of Economics*, *129*(1), 61-103.

Krueger, D., Perri, F., Pistaferri, L.; Violante L. G. (2010) Cross-sectional facts for macroeconomists. *Review of Economic Dynamics, 13*(1), 1-14.

Krusell, P.; Ohanian, L.; Ríos-Rull, J.; Violante, G. (2000) Capital-skill complementarity and inequality: a macroeconomic analysis. *Econometrica, 68*(5),1029-1053.

Krusell, P.; Smith, A. A. (1998) Income and wealth heterogeneity in the macroeconomy. *Journal of Political Economy*, *106*(5), 867-896.

Lucas, R. E. (1987) *Models of Business Cycles.* New York, Basil Blackwell.

Lucas, R. E. (2003) Macroeconomic priorities. *American Economic Review, 93*(1), 1-14.

Malinvaud, E. (1987) The overlapping generations model in 1947. *Journal of Economic Literature, 25*(1),103-105.

McKay, A.; Reis, R. (2016) The role of automatic stabilizers in the us business cycle. *Econometrica, 84*(1), 141-194.

Moll, B. (2017) Inequality and Macroeconomics. University of Luxembourg/European Investment Bank "Inequality and...?" Lecture Series. https://benjaminmoll.com/wp-content/uploads/2019/07/inequality$_$macro.pdf.

Oh, H.; Reis, R. (2012) Targeted transfers and the fiscal response to the great recession. *Journal of Monetary Economics*, *59*, S50-S64.

Pasinetti, L. L. (1962) Rate of Profit and Income distribution in relation to the rate of economic growth. *Review of Economic Studies*, *29*(4), 267-279.

Peterman, W; Sager, E. (2016) Optimal public debt with life cycle motives. FEDS Working Paper 2018-028.

Samuelson, P. A. (1958) An exact consumption-loan model of interest with or without the social contrivance of money. *Journal of Political Economy*, *66*(6), 467-482.

Yellen, J. (2016) Macroeconomic Research After the Crisis. The Elusive 'Great' Recovery: Causes and Implications for Future Business Cycle Dynamics, 60th annual economic conference sponsored by the Federal Reserve Bank of Boston, Boston, Massachusetts. Retrieved from https://www.federalreserve.gov/newsevents/speech/yellen20161014a.htm.