Barcelona School of Economics

Master Degree in Economics and Finance - PhD track

# Novel Avenues for Economic Policy: Insights from Heterogeneous Agents Models

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Advisor: Kadir Özen

22 July 2022

**Abstract in English:**
This literature review focuses on the contribution of the heterogeneous agents framework to the empirical robustness of macroeconomic models. First, we focus on the transmission of monetary policy in an economy characterized by heterogeneous agents. We do this by analysing both the quantitative HANK model and an analytical representation (THANK). Secondly, we illustrate the greater suitability of heterogeneous agent models for economic and welfare analysis in a developing country context. Finally, we analyze agent-based models as a potential avenue to address a higher degree of heterogeneity and complexity in the data.

**Abstract in Spanish:**
Esta revisión de la literatura se centra en la contribución del marco de agentes heterogéneos a la solidez empírica de los modelos macroeconómicos. Primero, nos enfocamos en la transmisión de la política monetaria en una economía caracterizada por agentes heterogéneos. En particular, analizamos el modelo cuantitativo HANK y una suya representación analítica (THANK). En segundo lugar, ilustramos que el modelo de agentes heterogéneos es mas idonio para el análisis económico y del bienestar en el contexto de un país en desarrollo. Finalmente, analizamos los modelos "agent-based" como una potencial solucion para modelar un mayor grado de heterogeneidad y complejidad en los datos.

**KEYWORDS IN ENGLISH:** Heterogeneity, Policy, Inequality.
**KEYWORDS IN SPANISH**: Heterogeneidad, Política, Desigualdad.

# Master Project

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# 1 Introduction

The economic literature has traditionally relied on the assumption that to understand aggregate dynamics we can study the behavior of a representative agent. This approach has often led to inaccurate predictions in the theoretical models of different fields in macroeconomics. Therefore, a new line of research has emerged in an attempt to introduce heterogeneity across agents and have a better representation of a reality which is characterized by a high degree of inequality. This literature review summarizes some important contributions in the fields of monetary policy and development, as well as new avenues for macroeconomic models characterized by a high degree of heterogeneity.

Kaplan et al. (2018) identify a key issue in Representative Agent New Keynesian (RANK) models for monetary policy. In this framework, the agent is a permanent income consumer with little sensitivity to transitory income changes. Hence, a monetary policy shock is transmitted to household consumption mainly through the direct channel of intertemporal substitution. However, empirical evidence suggests that direct effects should have a smaller weight on the total general equilibrium effects, while indirect channels such as changes in wages and transfers should be dominant. To address this, the authors develop a Heterogeneous Agent New Keynesian (HANK) model with two assets and idiosyncratic income shocks. With this, they obtain wealth and income distributions closer to empirical ones and find that equilibrium feedbacks are crucial in determining consumption response. Furthermore, the authors argue that Ricardian equivalence no longer holds in this setting due to the presence of Hand-to-Mouth households. This implies that the fiscal instrument chosen to react to the shock is relevant to determine the effectiveness of monetary policy.

The HANK models feature high complexity and cannot be solved analytically. Recent criticism against macroeconomic theory has been calling for simpler models that can improve the communication about policy prescriptions. This is the aim of Bilbiie (2017), that outlines the Tractable Heterogeneous Agents New-Keynesian model (THANK) for monetary policy, which is able to provide closed form solutions.

In contrast with the HANK, in the THANK model idiosyncratic income risk arises only from the possibility of becoming financially constrained, making the solution of the model easier. Moreover, the author shows how this model allows to address important questions in the literature about determinacy, Forward Guidance puzzle, amplification and optimal monetary policy. This paper builds on an earlier work, Bilbiie (2007), that outlines the Two Agents NK model (TANK) which can also be interpreted as a specific parametrization of THANK. An interesting connection between the TANK and the HANK models is discussed in Debortoli and Galì (2018). The authors argue that a TANK model approximates well the aggregate results of the HANK model.

Buera et al. (2021) use a macroeconomic model of entrepreneurship with heterogeneous agents and financial frictions to simulate the effect of scaling up microfinance projects to the whole economy. They find that in short run partial equilibrium, the introduction of microfinance increases capital and output, but causes total factor productivity (TFP) to fall. This is in line with findings from micro-evaluations. In long run general equilibrium though, capital decreases while TFP increases, leading output to remain more or less stable. There are welfare gains for most agents though, especially for the poorest, the marginal entrepreneurs and the very wealthy. These effects crucially hinge on agents being heterogeneous in their wealth and productivity.

Dosi and Roventini (2019) argue for a novel approach to macroeconomic modelling: the agent-based models (ABM). The ABM challenge the three main assumptions of Dynamic stochastic general equilibrium (DSGE) models: rationality, greed and equilibrium. In doing so, the ABM draws from recent results of behavioral economics to model the actions and interaction among agents in the economy. In this framework, ABM are, almost by construction, able to replicate microeconomic and macroeconomic regularities. This data-driven and highly heterogeneous approach is able to give us new insights on monetary policy effects. In particular, Dosi et al. (2013) shows the deep connections between monetary policy and patterns of income distribution.

The rest of the literature review is organized as follows. Section 2 discusses the

HANK model, Section 3 outlines a tractable version of it (THANK model), Section 4 describes a macroeconomic simulation of the up-scaling of microfinance, Section 5 introduces agent-based models. Section 6 concludes.

# 2 Monetary Policy with Heterogeneous Agents

In *Monetary Policy According to HANK*, 2018, Greg Kaplan, Benjamin Moll and Giovanni L. Violante develop a Heterogeneous Agent New Keynesian (HANK) model to study the transmission mechanism of a monetary policy shock to household consumption. The authors focus on decomposing the effects of the shock into direct and indirect general equilibrium effects. A problem that arises in Representative Agent New Keynesian (RANK) models is that the direct effects of a monetary policy shock on household consumption outweigh the indirect effects of the shock. This finding obtained when using RANK models is not in accordance with empirical evidence. The literature documents a small change in consumption after a change in interest rate when controlling for income, a large aggregate marginal propensity to consume (MPC) after transitory income shocks and a heterogeneous response across households. Kaplan et al. (2018) argue that, to find a substantial weight of indirect effects, the framework needs to allow for an accurate replication of the empirical distributions of wealth and marginal propensity to consume. To attain this, the authors build on a New Keynesian model and add uninsurable idiosyncratic income shocks while allowing households to self-insure by resorting to two saving instruments that differ in the degree of liquidity and rate of return. While the setting of the RANK model features a representative Ricardian household that is sensitive to interest rate changes but not to transitory income shocks, the model developed in this paper allows for the presence of poor and wealthy hand-to-mouth households that respond strongly to changes in income.

## 2.1 Model

The model incorporates a continuum of households that differ in their holdings of illiquid assets $a$, liquid assets $b$, and the idiosyncratic labour productivity $z$. Labour productivity follows an exogenous Markov process and time is continuous. The state of the economy at each moment in time $t$ is given by the joint distribution $\mu_t(da, db, dz)$. The difference in the degree of liquidity between the two assets arises from the fact that households have to bear a cost to make a deposit or a withdrawal from the illiquid account. This implies that the return on the illiquid asset is higher than the return on the liquid asset. When it comes to the latter, households are also allowed to borrow up to an exogenous limit $\underline{b}$.

The two-asset structure of the model allows the introduction of capital. Therefore, the resources of the illiquid account can be invested either in capital or in equity shares of the aggregate portfolio of intermediate firms. As argued by the authors, the introduction of capital is a key feature of the model as monetary policy transmission depends on how the price and quantity of capital respond to the shock. Furthermore, the two-asset structure allows to generate simultaneously a high aggregate wealth-to-output ratio and a high average MPC, which a one-asset HANK model cannot do.

On the firms' side, there is a representative final-good producer but monopolistic competition in the production of intermediate goods. The intermediate producers face quadratic costs when adjusting prices (Rotemberg pricing), from where price stickiness arises. Capital and labour markets are competitive.

The government collects a progressive tax on household labour income with a tax rate $\tau_t$, gives lump-sum transfers $T_t$ to households and faces government expenditures $G_t$. Furthermore, it is the only issuer of liquid assets $B_t^g$, with negative values of this variable representing government debt. The monetary authority follows a Taylor rule, with $\phi > 1$ and $\epsilon_t = 0$ in steady state: $i_t = \bar{r}^b + \phi\pi_t + \epsilon_t$.

Finally, the five markets of the economy clear: the bonds, capital, shares of the intermediate firms, labour and goods market.

### Transmission of the Monetary Policy Shock

Consider the effect of a one-time unexpected expansionary shock to the Taylor rule on the aggregate consumption at time $t = 0$. Since a change in the monetary policy shock $\epsilon_t$ implies a change in the liquid return $r_t^b$, the response at impact of consumption can be decomposed into direct and indirect effects of a shock to $r_t^b$:

$$dC_0 = \underbrace{\int_0^\infty \frac{\partial C_0}{\partial r_t^b} dr_t^b dt}_{\text{direct effect}} + \underbrace{\int_0^\infty \left( \frac{\partial C_0}{\partial w_t} dw_t + \frac{\partial C_0}{\partial r_t^a} dr_t^a + \frac{\partial C_0}{\partial \tau_t} d\tau_t + \frac{\partial C_0}{\partial T_t} dT_t \right) dt}_{\text{indirect effects}}$$

Direct effects refer to both the intertemporal substitution effect and the income effect that arises because aggregate liquid assets are in positive net supply and liquid asset positions vary across households.

Indirect effects can be decomposed into three channels: wages, illiquid return and government budget constraint. First, after a decrease in $r_t^b$, households that are not hand-to-mouth increase consumption via the direct channel of intertemporal substitution. This increases demand in the goods market which brings about a higher demand for labour and, consequently, a rise in wages. Second, a change in the liquid return will also influence the illiquid return. Hence, households might want to deposit or withdraw from their illiquid account. Finally, the government budget constraint becomes less tight via two channels. The rise in wages increases tax revenues. Furthermore, a decline in $r_t^b$ decreases interest payments on government debt. Therefore, the government should use one of the fiscal instruments to adjust its budget constraint.

**Details on Calibration**

Before calibrating the model, an assumption on how monopoly profits are distributed is introduced. In models with sticky prices only, expansionary monetary policy shocks shrink markups which cause firm profits to fall. In the model, this would imply that investment also falls, which is in contrast with the data. As a solution, the paper introduces $\omega$ as the share of profits reinvested into the illiquid account and sets this parameter equal to $\alpha$ to neutralize the effect of the countercyclicality of mark-ups on investment. The remaining profits are paid to households.

A key point in the calibration is to estimate the stochastic process for labour earnings, which is implemented using the Simulated Method of Moments and Social Security Administration data on male earnings. To estimate the frequency of arrival of earnings shocks, it is assumed that jumps following a normal distribution arrive at a Poisson rate $\lambda$ that is inferred from the data.

After calibrating the model, the authors obtain a distribution of MPCs in line with the literature. They are able to identify three groups: poor HtM households, with no liquid wealth and with high MPC; wealthy HtM households, that share the same characteristics as the first group but have positive illiquid wealth; and non-hand-to-mouth households, with small consumption responses and positive net liquid wealth.

In the baseline specification, the fiscal instrument chosen to balance the government budget constraint is the lump-sum transfers.

## 2.2 Results on Direct and Indirect Effects

To start with, the analysis of the impulse response functions reveals that the HANK model is able to deliver a higher total elasticity of consumption when compared to RANK models. Moreover, the indirect channels account for 80% of the response to the expansionary monetary policy shock which implies that direct effects play a much smaller role. This finding is one of the main contributions of the paper as it addresses the issue present in RANK models as mentioned.

Next, the authors study the elasticity of consumption and the split between direct and indirect effects at each level of the liquid wealth distribution with the goal of shedding light on why indirect effects are larger than direct effects. Then, the direct channel is decomposed into substitution, income and portfolio reallocation contribution effects, while the indirect component is divided into the impact coming from wages, illiquid return and transfers.

Regarding direct effects, the paper shows that these are larger for households close to hitting their borrowing constraint. For this group, the direct response is driven by the income effects of the drop in the interest rate - they face lower interest rate payments and can consume more as a consequence. Then, direct effects play less and less of a role for households close to zero liquid wealth, after which they start to increase. This happens because households with positive liquid wealth experience a substitution effect, that is very close to the one found in RANK models when liquid assets are high enough. It is also worth highlighting that households with positive but small levels of liquid wealth have small direct elasticities. Even though they are not at the kink of the budget constraint in the present, they might face it in the future, which drives their current MPC down when compared to households with high liquid holdings. Here the authors also emphasise the importance of introducing heterogeneity through uninsurable income shocks. With this, the model yields lower substitution effects than a TANK model, which does not allow households to change from the unconstrained to the constrained state.

When it comes to the indirect channel, the presence of non-Ricardian households is crucial to explain the importance of its role. Households with zero liquid wealth experience high indirect effects. The analysis shows that this happens because this group is highly sensitive to changes in wages and transfers.

## 2.3 Role of the Fiscal Response

Another key finding of the paper is that the instrument chosen by the fiscal authority to respond to the monetary policy shock matters for how consumption responds. In the case where transfers adjust, this channel will cause an increase in consumption from the side of high MPC households. However, when $G$ adjusts, this instrument contributes directly to an increase in output. As a result, the elasticity of output is found to be larger, even though the one of consumption is similar to the baseline. Another option is to let government debt adjust. In this scenario, the elasticities of output and consumption are smaller when compared to the baseline, and direct effects become more important. This stems from the fact that, in the baseline, transfers are an important factor driving up the consumption of HtM agents. Without this, indirect effects decrease in weight.

## 2.4 Monetary policy trade-offs

The authors conclude by studying the implications of the previous results on two monetary policy trade-offs. In the first place, in RANK, there is neutrality with respect to the timing of monetary policy. On the other side, in HANK, when shocks are persistent, a large part of the relaxation of the budget constraint associated with the interest rate cut occurs in the future. Hence, the increase in transfers that HtM households receive is smaller and the consumption response is weaker when shocks are smaller and more persistent. Thus, a sharper and more transitory shock is more powerful than a smaller but persistent shock in HANK. In the second place, the type of fiscal adjustment is also important to determine the slope of the inflation activity trade-off. For instance, adjusting the budget constraint by reducing government debt is found to be linked to a more favourable trade-off.

# 3 Tractable models for monetary policy

## 3.1 The THANK model

The class of HANK models features a high degree of complexity. They cannot be solved analytically and their policy conclusions are difficult to communicate. This made necessary the development of the models discussed in this section. The Tractable Heterogeneous Agents New-Keynesian model for monetary policy was outlined by Florin O. Bilbiie in *Monetary Policy and Heterogeneity: An Analytical Framework*, 2017. The main purpose of this model is to introduce heterogeneity across consumers in the basic New-Keynesian model in a tractable way that leads to closed form solutions. Moreover, the author shows how the model is helpful in addressing a number of questions in the literature.

**The basic environment**

The THANK model features a continuum of households that switch in discrete time between two states, or types: the Hand-to-Mouths and the Savers. The change in type of each agent follows a Markov process and occurs exogenously. The agents exhibit precautionary saving motives and have to face uninsurable idiosyncratic risk (only) across types, while there is full insurance within each type. Therefore, in contrast with the HANK model, there is no need to track the wealth distribution of the agents to assess how many agents hit the borrowing constraint.

The peculiarity of the Hand-to-Mouth agents is that of being financially *constrained*, in the sense that they are assumed to have hit a borrowing constraint, they have no access to any asset market and thus consume all their disposable income, which is given by their wage and the transfers from the government.

Instead, the Savers are *unconstrained* and hold shares of a productive firm, from which they receive dividends. These profits are taxed by the government and transferred to the Hand-to-Mouths. The shares of the firm are illiquid, in the sense that they do not survive a switch of state, and so they cannot be used to self-insure. In principle both agents can hold liquid bonds, which survive a change of state. Yet, in the basic version of the model they are zero in net supply and thus no bonds are held in equilibrium. The demand for bonds is well defined, but it cannot be met by the supply. Therefore, a shock that makes Savers increase consumption less than proportionally in order to self-insure results in income increasing less than proportionally as well, because the savings are not being invested in the economy.
Importantly, the saving and consumption choices of the Savers are described by an Euler equation, which takes into account the possibility of becoming constrained in the future.

The supply side of the economy is standard in the New-Keynesian environment. Monopolistic firms produce a continuum of goods and face price adjustment costs, which lead to the standard Phillips curve and a trade-off between inflation stabilization and real activity. Finally, in equilibrium there is market clearing in the goods and in the labor market.

**Cyclical inequality**

Inequality and the risk associated with it follow the business cycle dynamics. In particular, the idiosyncratic income risk is decomposed into *income inequality* and *pure risk*. The distinction is crucial for addressing some questions in the literature.

Income inequality is captured simply by the difference between the Savers' and the H-t-M's consumption. Its dynamics with respect to the business cycle depend on the fiscal policy in place. In fact, positive shocks to the economy entail an opposite income effect due to the fall in profits, consequence of the higher real wages needed to attract more labor. If the tax rate of profits (and thus the transfers) are low enough, the Savers are the ones that suffer more the income effect and therefore they increase consumption less than proportionally, while the H-t-Ms are mainly affected by the rise in the real wage and increase their consumption more than proportionally. This results in counter-cyclical inequality. Instead, when there is a high degree of redistribution, inequality becomes pro-cyclical, because now the H-t-M's resources depend crucially on the transfers and thus on the profits. After a positive shock, the strong income effect makes them increase consumption less than proportionally, while the opposite happens for the Savers.

By pure risk we mean the probability of switching to the constrained state. The probability can be modeled to be either counter- or pro-cyclical. When it is pro-cyclical, during expansions it is more likely to end up in the constrained state and as a result there are more H-t-M's agents, causing higher inequality. The opposite holds when risk is assumed to be counter-cyclical.

### The dynamic IS equation

The key novelty of the THANK model is that the features described above lead to a log-linearized dynamic IS equation that exhibits either discounting or compounding with respect to expected future income:

$$y_t = [\delta + \eta]\,\mathbb{E}\,y_{t+1} - \psi(i_t - \mathbb{E}\,\pi_{t+1})$$

where $y_t$ is income, $i_t$ is the nominal interest rate and $\pi_t$ is inflation. The three coefficients have the following meanings:

1. $\delta$: it captures the cyclicality of income inequality. When the latter is counter-cyclical, $\delta$ is greater than 1, because positive news about the future imply less inequality, more resources in the bad states of the world and less need to do precautionary savings, thus boosting consumption today. The opposite holds when income inequality is pro-cyclical: $\delta$ is smaller than 1.

2. $\eta$: it captures the cyclicality of pure risk. When it is counter-cyclical, we have that $\eta$ is positive, because positive news about the future imply less risk of becoming constrained in the future, and thus less need for precautionary savings. The opposite holds when risk is pro-cyclical: $\eta$ is negative.

3. $\psi$: it captures the direct effect of monetary policy on saving decisions. In the standard calibration it is positive, implying that the substitution effect dominates. Moreover, when income inequality is counter-cyclical, this parameter is increasing in heterogeneity: a monetary shock is amplified by the presence of many Hand-to-Mouth consumers, because the latter respond more than proportionally to income shocks.

The assumption about the size of these coefficients is crucial for addressing the questions outlined in the following paragraphs. The empirical literature seems to point both at counter-cyclical income inequality and risk.

**Macroeconomic analysis**

The THANK model allows to address a number of important questions in the literature: determinacy with interest rate rules, Forward Guidance puzzle, amplification and optimal monetary policy.

Regarding determinacy, if we assume that the Central Bank follows an interest rate rule that targets inflation ($i_t = \phi_\pi \pi_t$), we are guaranteed existence of a unique solution with the Taylor rule ($\phi_\pi > 1$) only if inequality is pro-cyclical enough. The intuition is that with pro-cyclical inequality the monetary shocks do not propagate too much, and so also a passive monetary policy is sufficient for determinacy. On the contrary, when inequality is counter-cyclical enough, shocks are amplified (in the DIS equation we would have compounding: $\delta + \eta > 1$) and determinacy requires a more aggressive monetary policy: $\phi_\pi >> 1$.

Secondly, if we want to model shocks' amplification due to income heterogeneity (that follows from counter-cyclical inequality, i.e. $\delta > 1$), which empirically seems more plausible, we face the Forward Guidance puzzle: the further in the future news about shocks are, the larger the effect today is. This can be easily seen in the DIS equation when $\eta = 0$, taking the derivative of income today with respect to $\mathbb{E}\, y_{t+T}$: $\delta^T$. The THANK model solves this issue by introducing risk cyclicality through $\eta$: if we assume that risk is pro-cyclical enough ($\eta < 0$), we can solve the FG puzzle by keeping the heterogeneity amplification feature ($\delta > 1$) and still having $\delta + \eta < 1$. The downside of this approach is that still there is not empirical evidence of pro-cyclical pure risk.

Finally, in the THANK model the monetary authority has an additional target: inequality. With respect to the Representative Agent New-Keynesian model (RANK), more inflation is tolerated, because there is a fraction of households that is not affected by the falling profits, when prices depart from the optimal level.

## 3.2 The TANK model

The THANK model builds on an earlier work of Bilbiie, *Limited Asset Markets Participation, Monetary Policy and (Inverted) Aggregate Demand Logic*, 2007, where he outlines the so-called Two Agents New Keynesian model (TANK). It can be interpreted as a specific parametrization of the THANK model, in which agents do not switch between types, and so we have that $\delta = 1$ and $\eta = 0$. Therefore, the main coefficient of interest is $\psi$, which captures the direct effect of monetary policy. The focus of the paper is on analysing the income and substitution effects and assessing which one drives aggregate results.

The presence of Hand-to-Mouth consumers amplifies the shocks to the economy, and reinforces the income effect, which in this model is borne entirely by the Savers. If the H-t-Ms are not too many, the income effect is dominated by the substitution effect, and $\psi$ is positive and increasing in the proportion of H-t-Ms. This parametrization is the standard in the literature.

Instead, when the proportion of H-t-Ms is above a certain threshold, the income effect wins and the monetary policy has an *inverted* effect on the aggregate economy: a monetary tightening becomes expansionary. This finding points at the importance of assessing the degree of asset markets participation in the economy, because the implied optimal monetary policy might change significantly.

## 3.3 TANK vs HANK

In *Monetary Policy and Heterogeneous Agents: Insights from TANK Models*, 2018, D. Debortoli and J. Gali discuss a useful connection between TANK and HANK models.

The aggregate fluctuations due to heterogeneity in the HANK models can be attributed to changes in the income gap between constrained and unconstrained consumers, changes in the dispersion *within* the unconstrained agents and changes in the share of constrained agents. The last two effects tend to offset each other, as when more consumers become unconstrained, they increase the mass of *poor* unconstrained agents, leading to higher dispersion within the group.

Therefore, the income gap emerges as the main source of aggregate fluctuations. It is a feature captured also by a TANK model, which in turn approximates well a richer HANK, as far as it concerns aggregate dynamics. The TANK model has a better tractability and is easier to solve, but it does not allow to address a number of issues related to wealth distribution, idiosyncratic risk and welfare, as discussed in the previous section.

# 4 Heterogeneous Agents in Development

The paper considered here, *The Macroeconomics of Microfinance*, by Francisco J. Buera, Joseph P. Kaboski and Yongseok Shin, illustrates how models with heterogenous agents can shed light on the macroeconomic effect of micro-level interventions in development. In the case considered, while there are many evaluations of single microfinance projects through randomized controlled trials (RCTs), there was previously no assessment of the macroeconomic dynamics of these projects when scaled up to the entire economy. This goal naturally calls for a modelling approach, and since welfare implications, especially for the poorest, are of foremost interest in this context, we are particularly interested in distributional consequences.

## 4.1 Integration in Literature

As Buera et al. (2021) summarize, a wide range of evaluations has shown that microfinance generally succeeds at increasing credit, entrepreneurial activity and investment, but that it has hardly any effect on income or consumption. Only if publicly subsidized and the interest rates thus being lower, there is consistently an increase of consumption and income as well. As a caveat, these evaluations typically suffer from statistical challenges and null results are often imprecisely estimated, with wide confidence intervals that include bigger effect sizes. The innovation of the present paper lies in taking a model of entrepreneurship with financial constraints, into which the authors introduce microfinance as a new technology that gives all agents access to credit and guarantees full repayment of a loan of limited size. Calibrating this model to Indian macroeconomic data, they simulate the short-run partial equilibrium and long-run general equilibrium effects of this innovation.

## 4.2 Model

The economy is populated by a measure N of individuals living indefinitely. They are heterogeneous in their wealth $a$, labor productivity $x$ and the quality of their entrepreneurial idea $z$. Wealth is endogenously determined, as a product of previous periods' shocks and saving decisions. Labor productivity $x \in [x_l, x_h]$ evolves according to a two-state Markov chain with symmetric transition matrix and diagonal element $\pi_x$. $z$ is drawn from an invariant distribution function, and entrepreneurial ideas become worthless at rate $1-\gamma$. The two shocks are independent from each other. Individuals maximize the discounted sum of their life-time utility, having CCRA preferences. At the beginning of each period, the shocks are realized and individuals choose whether to work earning $wx$, or to be an entrepreneur with production function $zf(k,l) = zk^{\alpha}l^{\theta}$.

Before the introduction of microfinance, entrepreneurs rent capital for production from competitive financial intermediaries, which constitutes the only form of "credit" in this economy. Entrepreneurs can run away with a fraction $\phi$ of the depreciated capital and of their revenues minus the wage payments. In that case, the financial intermediaries keep the wealth $a$ deposited with them. Thus, there is a financial friction in the form of a collateral constraint: The upper limit of capital that can be rented is the largest one where entrepreneurs still choose to repay rather than renege on the contract. This limit is by assumption smaller than the profit-maximizing amount of capital.

Microfinance is introduced as an innovation in financial technology guaranteeing the repayment of a loan up to an amount $b_{MF}$. Intermediaries earn the same as on traditional loans, but for borrowers, the interest rate is higher: $r_{MF} = r + v$, where r is the deposit rate and v an intermediation cost for $v > 0$ and a subsidy for $v < 0$. Individuals can use these loans for future capital rental, and importantly now also for consumption. These microloans interact with the conventional capital market in the sense that since microfinance loans are guaranteed to be repayed, they are assumed to be senior to credit in the conventional capital market. This defines a now lower maximal amount of conventional capital rental at which the entrepreneur will still fulfill the contract. This means that those who could rent only little or no capital before can now access at least the microloan amount for sure, while those who obtained a substantial amount of capital before, see microfinance offset some of this capital. Microfinance thus disproportionately benefits the poorer individuals.

A stationary competitive equilibrium consists of invariant wealth and productivity distributions together with "individual decision rules on consumption, asset accumulation, occupation, labour input and capital input" (Buera et al., 2021) such that

1. given the state, the decision rules solve the maximization problem
2. financial intermediaries make zero profit
3. capital, labor and goods markets clear
4. the joint distribution of wealth and entrepreneurial productivity is a fixed point of the equilibrium mapping

## 4.3 Findings

Then the authors calibrate the parameters of the model to standard values in the literature for preferences and to Indian macroeconomic data. First, as an exercise, they simulate the short-run partial equilibrium (PE) model prediction, calibrating the remaining parameters $v$ to the spread between conventional and microfinance loans, and $b_{MF}$ to the average loan size in two different micro-evaluations (Banerjee et al. (2015), Banerjee et al. (2017)/ Kaboski and Townsend (2011), Kaboski and Townsend (2012)). The first two papers evaluated a program without subsidies, the second two with. The authors show that generally the mechanisms in the model conform in direction and magnitude with the ones in the two RCTs. Subsequently, now concentrating on the non-subsidized case, they simulate the model prediction for different levels of $b_{MF}$ in short-term PE. They find that there is a higher proportion of entrepreneurs and that as a consequence TFP decreases because less productive entrepreneurs enter the market. Capital increases though, such that overall GDP increases. More precisely, for the highest simulated value of $b_{MF}$, $b_{MF} = 2w_0$, capital and output increase by 16% , TFP shrinks by 4% and there are 10 percentage points more entrepreneurs. Here in partial equilibrium, capital and labor markets do not clear, demand exceeds supply in both cases, requiring an inflow of capital and labor from from outside the economy.

Next, the authors simulate GE short run effects, meaning markets are now required to clear. Then, wages rise by 4% and the interest rate by 4 percentage points, continuing to consider the highest simulated value of $b_{MF}$. First, the capital stock is now lower as aggregate savings decline since microfinance lowers the necessity of precautionary savings. The fraction of entrepreneurs increases by only 2 percentage points, so that the average productivity of the newly entering entrepreneurs is unchanged. The increase in TFP of 3% comes from the larger number of entrepreneurs (given decreasing returns to scale) and from capital being allocated more on basis of productivity than on basis of wealth. As a result, output also rises by 3%, substantially less than before because of the now lower capital stock.

In long-run GE, as the economy reaches a new stationary equilibrium, the effects accumulate so that the interest rate is up by more than 5 percentage points, and the decline in capital is now up to 8%. TFP increases though, as the increase in the interest rate prevents the entry of less productive entrepreneurs. In sum, output remains stable. Taken together, given that output is approximately the same and savings are lower, consumption is higher, which constitutes a welfare gain. This is true even more in transition because output is still higher, but savings rate already lower. The authors then look at how these welfare gains are distributed along different levels of wealth, entrepreneurial and labor productivity, for a fixed value of $v = 0.12$ and $b_{MF} = 0.34$. Almost all gain. In partial equilibrium, it is especially the relatively poor that gain because they can use microloans to smooth consumption. Moreover, also the marginally productive entrepreneurs gain disproportionately much since microfinance affects their credit constraints more. This is even more so if their labor productivity is low, meaning that they switch to entrepreneurship already at lower entrepreneurial productivity and have then with higher probability accumulated little wealth when they worked. In GE, this effect on the marginally productive entrepreneurs is much smaller because higher wages and interest rates deter them from becoming entrepreneurs. Those with low entrepreneurial productivity have a higher welfare gain than in PE because they are likely to be workers and wages are now higher. The most wealthy benefit the most in all cases in GE since the higher interest rates give them a higher return on their wealth.

## 4.4 Discussion

The key take-away here is that the effects in short-run PE, i.e. those measured in micro-evaluations, are quite different from those in GE, i.e. what would happen if the project was scaled up to the entire economy. This is an important word of caution, given that most often in development economics, RCTs are used to test interventions for poverty reduction, with the aim of eventually scaling these interventions up if they can be shown to work. As demonstrated in this paper, it can however not just be assumed that the effects will translate to the larger scale.

In order to get to this conclusion, the authors at no point even consider representative agents. The type of analysis they set out to do would simply not be possible because key dynamics in this model come from the interplay of different levels of wealth and entrepreneurial/labor productivity, that would be impossible to simulate with a representative agent. Furthermore, by its very design, microfinance is targeting the poorest in an economy, and has in mind an improvement of their living conditions. We are thus concerned with welfare and distributional consequences that cannot be analyzed with representative agents. Moreover, key features and heterogeneity in the data could not be captured, such as the effects on the marginally productive entrepreneurs. In that sense, the heterogeneous agents framework opens up a way of macroeconomic modelling within development that caters to the purpose of the discipline and was previously impossible.

# 5 Agent-based Models

## 5.1 Motivation

Heterogeneous agent models, including HANK and THANK, have the merit to introduce some form of heterogeneity in the representative agent's framework. However, according to Dosi and Roventini (2019) in the paper *"More is different ... and complex! the case for agent-based macroeconomics"*, heterogeneous agents' models are still relying on unrealistic assumptions of the model which fail to capture the complexity of an economy. Namely, the assumptions contested are the three main pillars of DSGE models: rationality, greed and equilibrium (Colander (2005)). In addition, even heterogeneous agents models within the DSGE framework, such as the HANK model, are able to accommodate only rough and limited forms of heterogeneity while disregarding the effect of interaction among agents. As an example, heterogeneous agents models fail to fully characterize the impact of credit and finance on real economic dynamics since they do not model channels such as the behavior of banks (e.g. endogenous risk-taking), network dynamics, financial contagion, the emergence of bankruptcy chains and the implications of endogenous money. In this regard, the authors argue that DSGE models, including their heterogeneous agents' extensions, are simply post-real (Romer (2016)). A potential avenue to address these modellistic challenges is to rely on Agent-Based Models (ABM).

## 5.2 Building blocks

Agent-based economics is defined as the computational study of economies intended as complex evolving systems. ABM analyze the economy as an ecology populated by heterogeneous agents, "whose far-from-equilibrium local interactions yield some collective order, even if the structure of the system continuously changes" (Dosi and Roventini (2019)). The main concern of ABM is to build macroeconomic models from the bottom up with assumptions on agent behavior and interactions rooted in the actual microeconomic evidence. In order to facilitate the understanding of this class of models, we will analyze some building blocks comparing ABM models with their DSGE counterparts.

- *Bottom-up vs top-down approach.* According to DSGE models, including heterogeneous agents' extensions, the explanation of a given economic phenomenon (e.g., recession) can be summarized and explained by a few equations which govern the behavior of single components of the system. In the standard specification, these equations accommodate for an exogenous shock component, which is usually identified as the "cause" of the economic phenomenon. This usually entails strong consistency requirements associated with equilibrium and hyper rationality. In other words, we can explain economic phenomenon starting from simple equations which summarize the response of the whole economy for given variables (i.e., top-down or reductionist approach). By contrast, ABM models follow a so-called bottom-up (or generativist) approach. In other words, aggregate phenomena (e.g., recession) must be obtained as the macro outcome of a possibly unconstrained micro dynamics going on at the agents' level. According to the latter approach, a given phenomenon in the economic system (e.g., recession) might not be explained necessarily by an equation at the macro-level. In this regard, a recession might not be caused directly by an exogenous shock. Rather, a given phenomenon might be caused by the sequence of decisions (and of resulting constraints) that occur in the time lapse between the shock and the phenomenon (i.e., sequence causality, see Hicks et al. (1980)).

- *Aggregation results.* DSGE models often imply a small role for idiosyncratic shocks at the aggregate level. In general, idiosyncratic shocks are assumed to average out at the aggregate level with the immediate consequence that single agents (e.g., consumer, firms) might have a limited role in aggregate results. Conversely, the ABM entails the so-called *autocatalyticity* property. The latter property ensures that the behavior of the entire system is dominated by the elements with the highest auto-catalytic growth rate rather than by the typical average element. Due to *autocatalyticity*, idiosyncratic shocks may have aggregate consequences. In other words, an agent specific negative shock may turn into a macroeconomic recession, provided the agent is "big" enough or "connected" enough. The *autocatalyticity property* is implied by the fact that according to ABM, the micro and macroeconomic levels do not share the same structure. Given that, according to the level of aggregation, we may find different dynamics in the economies, such as new phenomena (e.g. business cycles and self-sustained growth), new statistical regularities (e.g. Phillips curve), and completely new structures (i.e. market institutions).

- *Rationality and foresight of agents.* One of the building blocks of DSGE models concern the perfect rationality and foresight of agents. In other words, modellers assume that agents are utility maximizers having the same information as do the economists in the model (see Fagiolo and Roventini (2016)). By contract, ABM draw from the body of evidence provided by cognitive psychologists and behavioral economics to introduce behavioral patterns based on bounded rationality with adaptive expectations (e.g., myopic optimization rules). As a consequence, in ABM agents are assumed not to be global optimizers, rather they are assumed to use simple rules (rules of thumb) based on local information.

## 5.3 Model

**Basics**

- **Time and Agents**. Time evolves in discrete time steps $t = 1, 2, ...$ There is a population of agents (e.g., consumers, firms, banks, etc.) possibly hierarchically organized.

- **Microeconomics factors**. At each $t$ every agent $i$ is characterized by: (a) *Time-varying microeconomic variables* $x_{i,t}$ (e.g., production, consumption, wealth); (b) *Time-fixed vector of micro-economic parameters* $\theta_i$ (e.g. mark-ups, propensity to consume).

- **Macroeconomic factors**. The economy is characterized by some macroeconomic fixed parameters $\Theta$ (e.g., tax rates, Basel capital requirements etc.).

- **Timeline**. Given some initial condition $x_{j,0}$ and a choice of micro and macro parameters (i.e. $\theta_i$ and $\Theta$) at each time step $t$ agents are chosen to update their micro-economic variables. Agents picked to perform the updating stage do so by using rule of thumbs which take into consideration their knowledge about their own history, local environments (including the state of agents they interact with), as well as the limited information about the state of the whole economy. Such dynamic is the outcome of behavioral assumption on the agents and, in principle, does not exclude that the agent might use also optimizing rules (as in DSGE models). After the updating round has taken place, a new set of micro-economic variables, is fed into the economy for the next-step iteration. In this regard, the model is always out-of-equilibrium (i.e., only a share of agents can update their state at each period). Aggregate variables $X_t$ are simply computed by summing up individual characteristics.

**Design and validation**

The most adopted procedure for the design and validation of ABM is the so called *indirect calibration approach* (Fagiolo et al. (2007)). This procedure is composed of three separate steps:

1. *Stylized fact identification.* Agent-based modellers identify a set of micro and macro stylized facts and empirical regularities which they want to replicate. Examples of micro and macro stylized facts that have been replicated are: fat-tailed distribution of returns, endogenous emergence of flash crashes, Okun and Beveridge curve, cyclical co-movements of variables in macroeconomics.

2. *Model specification.* Given a list of stylized facts that the researcher wants to replicate, ABM try to find an explanation of the underlying causal force. The great advantage as well as potential drawback is that in this step the researcher is free to take the modelling choices on agents' behavior and interactions based on empirical evidence or theoretical beliefs.

3. *Validation.* After the modellers have specified the behavioural equations of the actors populating the system, the ABM takes the form of a high dimensional, discrete-time stochastic process. We have two sub-steps in the validation procedure: (a) *Input validation*: to check whether the modelling assumptions about individual behaviors and interactions can be replicated in laboratory experiments and whether they are supported by the theory; (b) *Output validation*: ABM are usually simulated by means of extensive Monte Carlo (MC) exercises in which the random seed is modified along the MC dimension. Once the result of such MC exercises is observed and the synthetic data collected, the researcher can verify whether the model is able to generate micro and macroeconomic variables which are not statistically significantly different from the ones observed in real world datasets. In various applications, ABM were able to reproduce macroeconomic stylized facts such as endogenous growth, economic fluctuations, the emergence of banking crisis and deep down turns.

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## 5.4 Monetary policy in ABM

One of the main advantages of agent-based models is their fit to answer policy questions. As a matter of fact, ABM do not impose any strong theoretical consistency requirements (e.g. equilibrium, representative, individual assumptions, rational expectations) and assumptions can be replaced in a modular way, without impairing the analysis of the model. This is because they do not require ex-ante to be analytically solvable. In other words, the modeller has great freedom in interchanging assumptions and elements in the model.
A growing set of agent based models employ Taylor Rules to analyze the effect of monetary policy on the economy. In this regard, monetary policy exercises conducted with ABM are similar to the ones conducted with DSGE models. However, the complexity and heterogeneity richness of ABM can bring new key insight on monetary policy. As an example in the Credit-augmented ABM (Dosi et al. (2013), the authors find as the main result a deep interaction between monetary policies and patterns of income distribution. This interaction is regulated by the relationship between markups and the economy response to monetary policy. When mark-ups rates

are sufficiently low (i.e., a proxy for low income inequality), the interest rate may affect real dynamics in significant but asymmetric ways. Specifically, high interest rates increase the fluctuations in output, increase average unemployment and bring the economy on a low-growth trajectory path. In addition, agent based models are able to simulate also bankruptcy rates which enriches the simulated effects of monetary policy. First, for each level of interest rate, average bankruptcy rates decrease with the mark-up rate. Second, bankruptcy rates are affected by interest rates positively (i.e. higher interest rates, higher bankruptcy rates) only when mark-up rates are below a certain threshold.

# 6 Conclusion

We have seen that models with heterogeneous agents can help match the data better on direct and indirect effects of monetary policy shocks, can be made tractable with THANK models, can help understand the macroeconomic effect of micro-interventions, and finally we saw further explorations into agent-based models.

The HANK model delivers a more accurate representation of the wealth and consumption distribution of households, but it still lacks important dimensions of household heterogeneity. For instance, the distribution of capital gains is crucial to match the empirical evidence on movements of capital and equity prices.

The THANK model attempts to give a tractable representation of the HANK model, keeping a certain degree of idiosyncratic uncertainty. Yet, in contrast with the latter, it is not able to address issues related to wealth distribution and welfare.

Even with heterogeneous agents, it is unclear whether macroeconomic simulations of the scaling up of micro-evaluations can really do more than making us aware and cautious of forces in general equilibrium that might alter the effects found in RCTs. Given the data-challenges in developing countries, the dimension of the informal economy, and in general the immense complexity that remains beyond what is captured in the models, the model predictions might still be inaccurate.

The introduction of agent-based models attempts to represent more complex and richer economic dynamics. However, this enhancement comes with some drawbacks.

First, researchers are left with almost arbitrary freedom in choosing the inputs of the models (e.g., behavioral equations governing agents' behaviour). Second, causal mechanisms in the model are unclear ("black box" critique).

Nevertheless, the introduction of the heterogeneous agents' framework makes macroeconomic models more suitable to capture the complex dynamics in real-world economies. We conclude that such development in the macroeconomic field is key to enhance the relevance of the models' policy prescriptions and to improve the ability of their empirical performance.

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