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Monetary Policy and Inequality under Household Heterogeneity and Incomplete Markets

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Abstract

Motivated by the empirical evidence of the effects of unanticipated nominal interest rate increases on the evolution of household inequality in Mexico, which highlight the importance of insurance mechanisms to deal with idiosyncratic risks, the paper uses a Heterogeneous Agent New Keynesian model to analyze the relationship between monetary policy and household inequality. The model is able to capture the main features that characterise both the business cycle dynamics, as well as the distribution of income and wealth. Results indicate that heterogeneity affects the transmission of monetary policy, and that the design of monetary policy has important distributive effects.

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1. Introduction

Despite important reductions since the mid 1990s, elevated levels of socio-economic inequality remain one of the characteristic features of Latin America. While the study of inequality has been one of the pillars of the work of institutions such as the United Nation's Economic Commission for Latin America and the Caribbean throughout its history,[1] concerns about rising income and wealth inequality in developed economies in the aftermath of the 2008–2009 financial crisis, have renewed interest in the study of inequality, its determinants and the policy alternatives to address it, as evidenced by the interest in the work of Piketty (2014).

From an economics point of view, moderate levels of inequality can in principle provide incentives to accumulate physical and human capital (Barro, 2000; Okun, 1975, 1977). However, there is mounting evidence that high and sustained levels of inequality can impinge upon macroeconomic performance and stability (Berg and Ostry, 2017; Ostry et al., 2014; Stiglitz, 2012).[2]

While distributive concerns figure prominently in the analysis of certain macroeconomic policies, such as fiscal policy, until relatively recently the analysis of monetary policy had traditionally abstracted from such considerations. The objective of this work is to contribute to the emerging literature on the relationship between macro-level shocks and micro-level heterogeneity (Kaplan and Violante, 2018), by focusing on the relationship between households' income heterogeneity and monetary policy shocks for the case of Mexico.

Traditionally the analysis and formulation of monetary policy has been carried out using some variant of the standard New-Keynesian Dynamic Stochastic General Equilibrium Model (DSGE). However, the use of a representative agent to summarise the demand-side of the economy precludes the analysis of distributive concerns.

As discussed by Krusell and Smith (1998) the assumption of a representative agent is equivalent to the assumption that markets are complete. Thus to meaningfully consider heterogeneity it is necessary to identify the sources of heterogeneity, as well as to introduce a certain degree of market incompleteness, for which it is necessary to identify the availability, or lack thereof, of appropriate insurance mechanisms (Guvenen, 2011).

With this consideration in mind, the paper begins with an empirical investigation into the nature of the relationship between monetary policy and households' income inequality in Mexico (Section 3). The results suggest that inequality of households' income increases as a result of an unanticipated increase in the nominal interest rate. In particular, in comparison to the reduction of income for households in the top quintile of the income distributions, the decrease in households' income is more pronounced for households in the bottom 80% of the income distribution.

Motivated by the empirical evidence, the paper then explores the relationship between household inequality and monetary policy in the context of a Heterogeneous Agent New Keynesian (HANK) model (Kaplan et al., 2018) (Section 4.1). In contrast to the traditional approach where the demand-side of the economy is summarised by a single representative agent, the model con-

[1] See CEPAL (2015) for a review of recent contributions.

[2] See Dabla-Norris et al. (2015) for a review of the macroeconomic causes and consequences of income inequality.

siders heterogeneous households which face idiosyncratic risks which they can not fully insure against. The model is calibrated using data from Mexico, and is able to capture the main features that characterise both the business cycle dynamics, as well as the distribution of income and wealth across households.

The results stemming from a series of counterfactual experiments indicate that the presence of heterogeneity impinges upon the transmission of monetary policy, and that the design of monetary policy has important distributive effects. With respect to the effect of heterogeneity on the transmission of monetary policy indicate that in comparison to the benchmark representative agent model, the contemporaneous "cost" of achieving a given reduction of inflation is over three times larger in terms of the reduction in output, and over four times larger in terms of the reduction in aggregate consumption. Concerning the impact of monetary policy on households' inequality, the results indicate that the effect of a standard deviation contractionary monetary policy shock (80 basis points) results in a contemporaneous reduction of 1% in the consumption of households in the bottom 80% of the income distribution, but only a reduction of 0,67% in the consumption of households in the top 20% of the income distribution.

Moreover, the findings suggest that a Taylor-type monetary rule which aggressively targets both inflation and deviations of output from its steady state level, can ameliorate the impact of monetary policy on households' income and consumption levels as well as on the resulting inequality.

2. Related literature

The paper is related to two strands of the literature. First it is related to the literature on the evolution and determinants of household inequality. Second it is related to the literature analyzing the characteristics of the transmission mechanism of monetary policy.

The analysis of the evolution and determinants of household inequality in Mexico over the long-run, López-Alonso (2007) finds that inequality of standards of living only improved for the elites over the period 1850–1950 despite the industrialization underwent by the country during the early 20th century.

Focusing on the second half of the 20th century, Cortés (2013), López-Alonso and Vélez-Grajales (2019) and Székely (2005), find that despite a modest reduction of household income inequality in the 1960's and 1970's, the debt crisis of the 1980's gave rise to an increase in inequality that did not abate until the late 1990s.

Campos et al. (2014), and Esquivel et al. (2010) find that the main contributor to the decline in household income inequality observed since the late 1990s, has been the reduction of inequality of labour income, driven mainly by a fall in the premium to skills. Esquivel et al. (2010) argue that the fall in the skill-premium reflects the impact on schooling of conditional cash transfers programs, as well as the expansion of targeted social programs. Binelli and Attanasio (2010) provide a detailed analysis of the evolution of cross sectional statistics for Mexico over the 1990s.

Recently, several authors including Campos-Vazquez and Lustig (2019), del Castillo (2017) and Reyes et al. (2017) have argued that despite the declining trend in inequality documented

by official data, mismeasurement of top-income earners results in underestimation of household level inequality.

This paper measures the impact of monetary policy shocks on households' income inequality as measured by the Gini coefficient. The empirical evidence indicates that an unanticipated increase of 80 basis points in the short-term nominal interest rate, equivalent to a standard deviation of shocks measured over the 2001–2014 period, have a contemporaneous impact on the Gini coefficient of households' labour-income of 0.02, and a cumulative impact of 0.12 over a three-year horizon. To contextualize the magnitude of the result, the households' labour-income Gini coefficient declined from about 0.45 in 2001 to roughly 0.39 in 2014.

The literature analysing the transmission channel of monetary policy in Mexico before the adoption of an inflation targeting regime in 2001 is very scarce (Sidaoui and Ramos-Francia, 2008). Since then, the literature has focused on the analysis of inflation dynamics, where using time series models Capistrán and Ramos-Francia (2009) and Chiquiar et al. (2010) find a significant reduction in the persistence of inflation as a result of the adoption of inflation targeting in 2001.

Gaytán and González (2006) find that a structural change in the transmission mechanism of monetary policy occurred after the adoption of inflation targeting, with inflation and nominal interest rates becoming less responsive to exchange rate fluctuations, and fluctuations in the nominal interest rate more influential in the evolution of the real exchange rate and inflation (Torres, 2003).

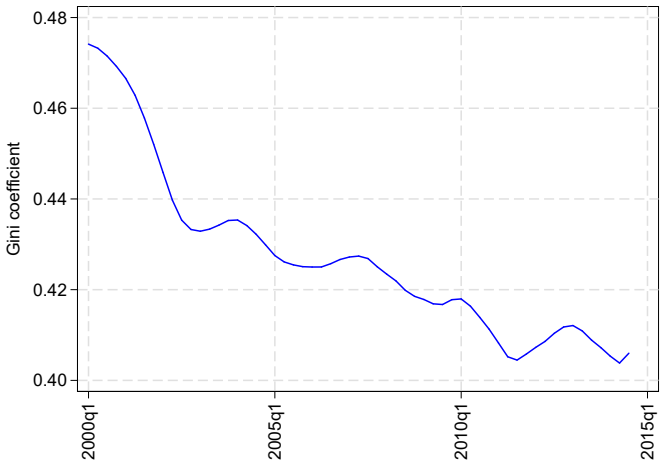
Using a small-scale macroeconometric model, Sidaoui and Ramos-Francia (2008) study the evolution and relative importance of the nominal exchange rate and credit channels in the transmission of monetary policy. Capistrán and Ramos-Francia (2010) and Ramos-Francia and Torres (2005) find evidence that the adoption of inflation targeting has also increased the importance of the expectations channel in monetary transmission.

Using a DSGE model, Best (2013) corroborates the diminishing importance of nominal exchange rates in the determination of nominal interest rates. Using a similar framework, Cermeño et al. (2012) find that the Central Bank in Mexico targets both inflation and the output gap. More recently, Zamarripa (2021) uses a DSGE model to examine the changes in the transmission mechanisms of monetary policy over the period 1995–2019.

To the best of my knowledge, this work is the first to analyse and empirically document the distributive impact of monetary policy, including the relevant transmission channels, as well as to investigate the role of households' heterogeneity on the effectiveness of monetary policy for the case of Mexico.

3. Households' Income Inequality and Monetary Policy Shocks

Although inequality remains one its distinctive features, in contrast to the rising trend observed in the developed world (Krueger et al., 2010; Galvin, 2020), inequality in Latin America fell significantly since the late 1990s until the mid 2010s (López-Calva and Lustig, 2010; Ferreira and Ravallion, 2009; UNDP, 2021). Notwithstanding the recent decline, inequality remains



Note: In order to improve the readability of the figure, the series shown were smoothed using a non-parametric locally weighted regression with bandwidth equal to 0.15. See appendix for details.
Source: Author based on data from INEGI (2001, 2007).

Figure 1. Mexico 2000–2014: Evolution of labour-income inequality.

elevated across Latin America.

In the case of Mexico, households' income inequality has exhibited an overall declining trend that began in the mid 1990s (Figure 1). The findings of Esquivel et al. (2010) indicate that over half of the observed reduction of income inequality can be explained by the reduction of inequality of labour income. In particular, after decomposing the reduction of labour income inequality into changes in the observable characteristics of the workforce, and changes in the returns to these characteristics, Campos et al. (2014) conclude that although changes in characteristics increased inequality of income, the dynamics of their returns compensated their effect and explain the observed reduction of households' labour-income inequality. The evidence underlines the importance of the relative rise in returns of low-skilled workers.

Table 1 summarises the main sources of household income by quintile from the 2014 survey data, which, as detailed below, corresponds to the end of the study period. On average, roughly two thirds of household's income stems from labour earnings, although its relative importance is heterogeneous across the distribution, ranging from 48.9% in the first quintile to 72.3% in the fourth quintile. In contrast, capital income, particularly that stemming from business ownership, is heavily concentrated in the top quintile

Within labour income, the composition between salaried work and independent work earnings is also heterogeneous with independent work earnings above the mean for all but the top quintile. This is relevant because as discussed by Porta and Shleifer (2014) the vast majority of independent workers work in the informal sector, which is characterised by very low productivity levels and has little, if any, to mechanisms that would allow them to insure themselves, such as access to social security and formal financial services.

As expected, transfers represent an important proportion of current income for the poorest households, with that proportion reaching 30.5% in the first quintile. However it should be noted

Table 1

Mexico 2014: Household income by quintile (current pesos).

	Total	Quintile I	II	III	IV	V
	(Proportion of total current income)					
Total Current Income	100.0	100.0	100.0	100.0	100.0	100.0
Labour Income	67.3	48.9	64.2	69.7	72.3	66.9
Salaried workers	56.9	32.6	51.0	57.8	61.4	58.3
Own-account workers	7.9	12.9	10.1	8.9	8.2	6.5
Other labour income	2.5	3.3	3.1	3.0	2.7	2.0
Capital Income	5.9	1.1	1.5	1.8	2.8	9.8
Business ownership income	4.7	0.7	0.9	1.3	2.0	8.0
Transfers	15.4	30.5	19.7	15.8	13.5	13.7
Imputed rent	11.4	19.2	14.5	12.6	11.4	9.6
Other Current Income	0.1	0.3	0.2	0.1	0.1	0.1

Source: Author based on INEGI (2015a).

that due to poor targeting, transfers received by households in the top quintile account for 13.7% of income. Finally, in contrast to the relevance of capital income, which increases with income levels, the proportion represented by imputed rent income declines as income increases.

Under an inflation targeting regime, such as the one used to conduct monetary policy in Mexico since 2001 (Banco de México, 2007), the policy instrument is a short-term interest rate, which in the case of Mexico is the overnight interbank lending rate.

Under the assumption that economic agents are forward-looking, agents will form expectations regarding the evolution of the policy rate. This means that, even in the presence of nominal frictions, if a rate change is fully anticipated the effect of the actual change on economic aggregates will be negligible. However, if the actual change is different from expectations, depending on the sign and magnitude of the discrepancy, as well as of the nature of nominal frictions, monetary policy can have significant effects on the economy at large (Galí, 2008). Thus, for the analysis of monetary policy the interest lies not on the observed changes in the policy rate, but on its unanticipated fluctuations, which are commonly referred to as monetary policy shocks.

There are several ways in which monetary policy shocks, which are unobserved, can be identified. For instance, the cross equation restrictions implied by a structural model, such as a DSGE model, could be used. However, even a small DSGE model such as the one used by Lubik and Schorfheide (2007) for small open economies, impose a number of cross-equation restrictions which may not necessarily be supported by the data. With this in mind, monetary policy shocks are identified by imposing restrictions on the impulse-response functions of a vector autoregressive (VAR) model. In particular, based on the work of Carrillo and Elizondo (2015), the following specification is used:

$$\begin{aligned} Z_t &= \alpha_Z + \sum_{i=1}^{p} D_i Z_{t-i} + \eta_t \\ Y_t &= \alpha_Y + \sum_{i=1}^{p} A_i Y_{t-i} + \sum_{i=1}^{p} B_i Z_{t-i} + \epsilon_t, \end{aligned} \tag{1}$$

where Z_t and Y_t are, respectively, vectors of exogenous and endogenous variables, α_Z and α_Y are vectors of constants, D_i, A_i and B_i are parameter matrices to be estimated, and the vector of errors $[\eta_t \epsilon_t]'$ is assumed to have mean zero, no serial correlation, and covariance matrix equal to:

$$\Sigma = \begin{bmatrix} \sigma_\eta & \sigma_{\eta\epsilon} \\ \sigma_{\epsilon\eta} & \sigma_\epsilon \end{bmatrix}.$$

The variables used are:

$$Y_t = \begin{matrix} \text{Output gap} \\ \text{Inflation gap} \\ \text{Producer inflation gap} \\ \text{Real exch. rate depreciation} \\ \text{Real interest rate} \\ \text{Real money growth} \end{matrix} \begin{bmatrix} y_t - \overline{y}_t \\ \pi_t - \overline{\pi}_t \\ \pi_t^p - \overline{\pi}_t \\ \Delta q_t \\ i_t - \overline{\pi}_t \\ \Delta m_t - \overline{\pi}_t \end{bmatrix}, \qquad Z_t = \begin{matrix} \text{US Output gap} \\ \text{US Inflation} \\ \text{Oil price inflation} \end{matrix} \begin{bmatrix} y_t^* - \overline{y^*}_t \\ \pi_t^* \\ \Delta wti_t \end{bmatrix}$$

where the domestic output gap $y_t - \overline{y}_t$ is obtained by computing the log difference of the level of the series y_t with respect to its Hodrick-Prescott (HP) filtered trend $\overline{y}_t$;[3] core consumer price inflation π_t, producer price inflation π_t^p, nominal interest rates i_t,[4] and nominal money growth Δm_t[5] are detrended using the HP-filtered trend for core consumer price inflation.[6,7] All domestic data, are from the Mexican statistical institute, except for the real exchange rate index which is from the Banco de México. US output and price data comes from the Bureau of Economic Analysis, and oil price data comes from the Energy Information Agency.[8]

As discussed by Fry and Pagan (2011), from the several types of restrictions that can be imposed on the impulse responses, in principle long-run (Blanchard and Quah, 1989) and sign restrictions (Canova and Nicoló, 2002; Faust, 1998; Uhlig, 2005) are the least restrictive.[9]

Considering this, in order to allow the data to "speak" as freely as possible, monetary policy shocks are identified under the assumption of (long-run) block-exogeneity of the exogenous variables and sign restrictions on the responses to aggregate supply, aggregate demand and monetary policy shocks as summarised in the following matrix:

	$y_t - \overline{y}_t$	$\pi_t - \overline{\pi}_t$	$\pi_t^p - \overline{\pi}_t$	Δq_t	$i_t - \overline{\pi}_t$	$\Delta m_t - \overline{\pi}_t$
Aggregate supply	+1	−1	−1	+1	×	×
Aggregate demand	+1	+1	+1	−1	+1	×
Monetary policy	−1	−1	×	−1	+1	−1

[3] Following standard practice, the Hodrick-Prescott filter is used with a smoothing parameter equal to 1,400.

[4] In contrast to the estimation of the DSGE model, where the overnight interest rate was used, the rate for 28-day Mexican treasuries (CETES) is used instead.

[5] The M2 monetary aggregate is used.

[6] All changes are quarter on quarter changes.

[7] Price inflation and changes on the level of GDP and the M2 monetary aggregate are computed on the basis of seasonally adjusted data.

[8] To price of West Texas Intermediate oil, which is the relevant commodity price for the case of Mexico, is used.

[9] Alternative restrictions include recursive identification as in Sims (1980), and restriction on the contemporaneous effect of shocks on system variables as in Galí (1992).

where ×'s imply no restriction. The estimation is carried out using the generalisation of the Rubio-Ramírez et al. (2010) algorithm due to Binning (2013).

3.1 Impulse-response Functions

As reviewed by Colciago et al. (2019), from a theoretical perspective the effect of monetary policy shocks on inequality is a priori ambiguous. The transmission channels can be broadly classified into direct and indirect effects (Ampudia et al., 2018).

Direct effects are the result of the effect of monetary policy shocks on households' incentives, as well as on the magnitude and composition of their net wealth. In the case of an expansionary monetary policy shock, in addition to the reduced incentive to save, the reduction in interest rates will shift resources from households with net financial assets towards those with net financial liabilities.

Indirect effects operate through the general equilibrium effects of monetary policy on macroeconomic aggregates. An expansionary monetary policy stance will boost economic activity, which will in turn generate additional demands for employment and upward pressure in wages. Reflecting the composition of household's income streams, this effect will have a differentiated impact on households.

For the case of Mexico, to the best of my knowledge the issue has not been examined directly. However, the available (indirect) evidence suggests that contractionary monetary policy shocks should increase labour income inequality, and the increase in inequality should be more acute among poorer households.[10]

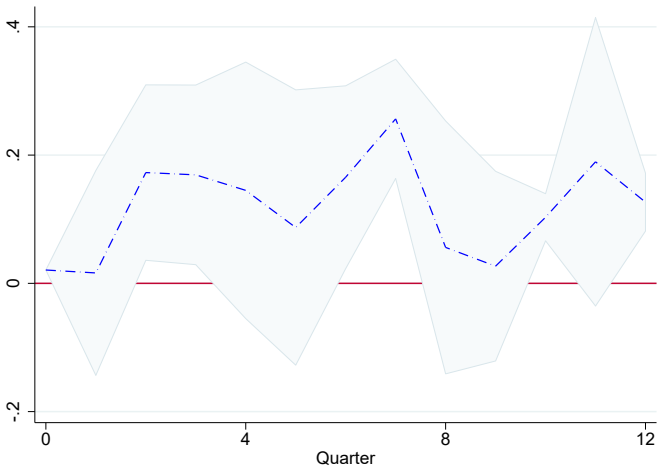
To investigate the impact of the monetary policy shocks on household inequality in Mexico, impulse response functions are estimated using the local projection method proposed by Jordà (2005). The advantage of using local projections instead of a traditional vector autoregresive model (VAR) is that the method is robust to misspecification, and approaches the results obtained using a VAR when it is the true data generating process (Plagborg-Møller and Wolf, 2020).

Figure 2 shows the cumulated response of the households' labour-income Gini coefficient to a standard-deviation sized monetary policy shock.[11] Although subject to a relatively wide estimation margin, the response is positive and statistically significant, implying that an unanticipated one-time increase in the short-term nominal interest rate equivalent to 80 basis points, raises the Gini coefficient of labour-income by 0.12, on average, over a three year period.

This implies that the income of different population groups respond differently to the same shock. As argued by Guvenen (2011), this reflects the availability of insurance mechanisms to face shocks. Households in the top quintile of the income distribution have a more diversified

[10] Using a standard small open economy DSGE, augmented to include formal and informal labour markets, Fernández and Meza (2015) find that a reduction in output decreases demand for labour and wages in the formal sector, leading to a reallocation of resources towards the informal sector as a result of a greater relative elasticity of labour supply in the formal labour market (Campos-Vazquez, 2010). According to Binelli and Attanasio (2010), this should result in greater wage inequality to the extent that wages in the informal sector are not constrained by labour market regulations.

[11] The standard deviation of monetary policy shocks observed over the period 2001.2 through 2014.3 is 80 basis points (0.8%).



Note: The graph shows the cumulated response to a monetary policy shock with magnitude equivalent to a standard deviation observed over the study period (80 basis points). The response is estimated using local projections over a 12-quarter period. The shadowed area around the impulse response is the 95% confidence interval.

Figure 2. Mexico: Impulse response of households' income Gini coefficient to a monetary policy shock.

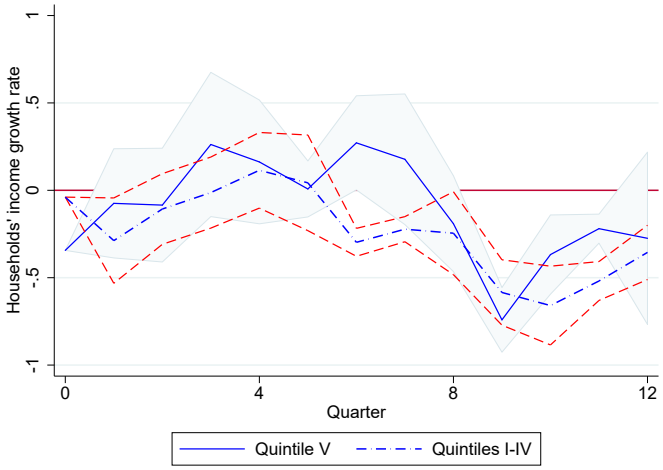
income stream, are more likely to be formally employed, and own the majority of assets in the economy, which in turn gives them better access to financial instruments to manage risk. Considering this, to investigate the impact of monetary policy shocks on different population segments, the households' sample is split into the top 20% and the bottom 80% of the labour-income distribution.

Figure 3 shows the cumulated response of the median household income of the top 20% (quintile V) and the bottom 80% (quintiles I-IV) of the sample to a standard deviation sized contractionary monetary policy shock. It can be seen that, as expected, the overall effect of an unanticipated increase in the short-term nominal interest rate is to reduce households' median income. While over the short term, the cumulative effect is not significantly different from zero for both groups, over the medium term, the contraction of the median income of households in the bottom 80% of the labour-income distribution is larger than the contraction observed for households in the top 20% of the labour-income distribution.

4. Household Heterogeneity and Incomplete Markets

The results of the preceding section indicate that contractionary monetary policy raises households' labour-income inequality in Mexico. The increased inequality is the result of a differentiated effect on the response of labour-income of households in the top quintile of the income distribution with respect to the rest of households. In principle, this reflects the greater access of richer households to mechanisms that allow them to insure themselves against the realisation of idiosyncratic risks such as spells of illness or unemployment.

Motivated by these findings and building upon the analytical framework proposed by McKay and Reis (2016), the objective of this section is to explore the relationship between monetary



Note: The graph shows the cumulated response to a monetary policy shock with magnitude equivalent to a standard deviation observed over the study period (80 basis points). The response is estimated using local projections over a 12-quarter period.

Figure 3. Mexico: Impulse response of households' median income level coefficient to a monetary policy shock, by income quintile.

policy and household heterogeneity when markets are incomplete, in the context of a dynamic stochastic general equilibrium model which can be used to examine counterfactual policy scenarios. In particular, the impact of monetary policy design on household inequality, and the feedback from inequality to the transmission of monetary policy are studied.

The model is able to replicate the main features of the distribution of income and wealth across households, as well as of the business-cycle fluctuations for the case of Mexico. Moreover, the properties under the baseline case are consistent with the evidence regarding the effect of monetary policy on inequality discussed in Section 3.

Counterfactual experiments are carried out to examine the response of the economy's aggregates to monetary policy shocks, under different assumptions regarding the degree of market incompleteness and preference heterogeneity, as well as the impact of the formulation of monetary policy on household inequality over the short- to medium-term.

4.1 Model

The model proposed by McKay and Reis (2016) combines the production structure of a standard New-Keynesian model as in Woodford (2003), with a demand-side characterised by heterogeneous households which cannot fully insure against idiosyncratic risks because markets are incomplete, as developed by Bewley (1986), Imrohoroğlu (1989), Huggett (1993) and Aiyagari (1994), and distilled in Kaplan et al. (2018). The model is solved numerically using a procedure that combines projection and perturbation methods due to Reiter (2009).

Despite the model's stylized nature, it affords the inclusion of three key features of the Mexican economy to explore the relationship between monetary policy shocks and households' income

inequality. First, the model is able to capture the high level of heterogeneity that characterizes the distribution of income and wealth across households. Second, the model also captures the limited availability of mechanisms to insure against the occurrence of shocks that affect labour income. Third, the model's policy blocks includes the conduction of monetary policy under an inflation targeting regime, as well as a procyclical fiscal policy.

Demand

The demand-side of the economy is comprised by two types of households, *entrepreneur* households which directly own the capital in the economy and can insure themselves against idiosyncratic risks, and *worker* households which do not own capital and can not trade in state-contingent securities which would allow them to offset idiosyncratic risks.

Entrepreneur Households. It is assumed that there exists a continuum with unit mass of entrepreneur households who maximise utility by choosing current consumption c_t, labour supply n_t, and investment which determines the next period's available capital k_{t+1}:

$$\max_{\{c_t\},\{n_t\},\{k_{t+1}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log c_t - \varphi_1 \frac{n_t^{1+\varphi_2}}{1+\varphi_2} \right] \tag{2}$$

$$\text{s.t} \qquad p_t[c_t + k_{t+1}] + \Delta b_{t+1} = p_t \left[(i_{t-1}/p_t) b_t + d_t + (1-\tau_t) w_t \bar{s} n_t + (1+r_t) k_t - \frac{\zeta}{2} \left(\frac{\Delta k_{t+1}}{k_t} \right)^2 k_t \right], \tag{3}$$

where β denotes the discount factor, φ_1 is the relative willingness to work, and φ_2 is the inverse of the Frisch elasticity of labour supply.[12]

Entrepreneur households maximise utility (2) subject to budget constraint (3), whose right- and left-hand sides describe, respectively, the resources available and their uses. In addition to final goods purchased at price p_t, which can be consumed or used as capital, households can save using single-period nominal bonds b_{t+1}, which are indexed according to their maturity date and can be traded with worker households and the government. Available resources include the nominal return of bond holdings from the previous period $i_{t-1} b_t$; dividends accruing from ownership of intermediate-goods producers d_t; labour-income $w_t \bar{s} n_t$ which is the product of the wage rate w_t, productivity $\bar{s}$ and hours worked n_t, and is subject to income tax rate τ_t; and net returns from the rental of capital which earns real rate r_t, and are subject to quadratic adjustment costs whose intensity is governed by parameter ζ.

A key assumption is that entrepreneur households can insure perfectly against idiosyncratic risk, which takes the form of productivity shocks and are discussed below. In particular, it is assumed they have access to trade in Arrow-Debreu type securities. Since all trades in contingent securities take place among entrepreneur households, they are in zero net-supply and thus drop out of the representative entrepreneur's household budget constraint. Moreover, since they can

[12] The Frisch elasticity measures changes in labour supply as a response to changes in wages when the marginal utility of wealth is held constant.

insure against specific realisations of labour productivity, only average productivity $\overline{s}$ enters the budget constraint.

Worker Households. It is assumed that there exists a continuum of worker households with a measure of mass η. Individual households, which are indexed by $h \in [0, \eta]$, solve a similar optimisation problem to entrepreneur households, although subject to a different budget constraint:

$$\max_{\{c_{h,t}\},\{n_{h,t}\}} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \hat{\beta}^t \left[\log c_{h,t} - \varphi_1 \frac{n_{h,t}^{1+\varphi_2}}{1+\varphi_2} \right] \tag{4}$$

$$\text{s.t} \quad p_t c_{h,t} + \Delta b_{h,t+1} = p_t \left[(i_{t-1}/p_t) b_{h,t} + (1-\tau_t) w_t s_{h,t} n_{h,t} \right], \tag{5}$$

where crucially, following Krusell and Smith (1998), it is assumed that $\hat{\beta} \leq \beta$ to be able to match the skewness that characterises the distribution of wealth in the data. The lower discount factor is interpreted as a higher subjective assessment of the uninsurable risk faced.

As a reflection of the limited participation of the majority of households in capital markets, it is assumed that worker households do not own capital.[13] Note that this does not preclude their participation in financing capital accumulation through net lending to entrepreneur households via the bond market, where they face the borrowing constraint $b_{h,t+1} > 0$.

Worker households are assumed to face a single uninsurable idiosyncratic risk, namely shocks to labour productivity s_h which give rise to a non-degenerate distribution of labour-income. Given the absence of meaningful unemployment benefits in the Mexican labour market, the vast majority of workers which are laid off from the formal sector usually migrate to the informal sector, which acts as a buffer for the labour market across the business-cycle (Fernández and Meza, 2015). Consequently, unemployment is not explicitly considered. Instead the transition matrix for the Markov-process driving the occurrence of productivity shocks is calibrated to match the dynamics of entry to and exit from the informal sector, which is characterised by lower wages as well as a certain degree of hysteresis (Bosch and Maloney, 2005).

Supply

Following the standard formulation in the New-Keynesian literature, the supply-side of the economy is comprised of a representative competitive final-goods producing firms, and a continuum of monopolistic intermediate-goods producing firms.

Final-goods firm. The representative final-goods firm combines differentiated intermediate goods according to the following function:

$$y_t = \left(\int_0^1 y_{j,t}^{-\mu_t} dj \right)^{\mu_t}, \tag{6}$$

where y_t denotes final-goods output, and μ_t is the elasticity of substitution between intermediate inputs $y_{j,t}$, which reflects the markup imposed by monopolistic intermediate-goods producers.

[13] According to the end of sample household survey data (INEGI, 2015a) the top quintile receives over 90% of business income.

The final-goods firm is assumed to be a price taker in the intermediate-goods market, which along with cost minimisation implies that demand for intermediate goods is given by:

$$y_{j,t} = \left(\frac{p_{j,t}}{p_t}\right)^{\frac{\mu_t}{1-\mu_t}} y_t, \tag{7}$$

where $p_{j,t}$ is the price of the j-th intermediate input. Given the functional form in (6), the price of final goods is given by:

$$p_t = \left(\int_0^1 p_{j,t}^{-(1-\mu_t)} dj\right)^{1-\mu_t}. \tag{8}$$

Intermediate-goods firms. Intermediate goods are produced by a continuum, with mass normalised to one, of monopolistic producers which seek to maximise dividends:

$$d_{j,t+s} = \frac{p_{j,t}}{p_t} y_{j,t} - w_t \ell_{j,t} - (r_t + \delta) k_{j,t} - \xi \tag{9}$$

subject to the demand schedule for intermediate goods (7). Production costs include wages w_t, the rent paid to capital r_t, plus depreciation δ and fixed production cost ξ.

Following Calvo (1983), it is assumed that there is an exogenous probability θ that intermediate-goods firms can adjust their prices during a particular period. When adjusting prices, monopolistic producers seek to maximise current and future profits $d_{j,t+s}$ for $s \geq 0$ by choosing a sequence of prices $\{p_{j,t+s}\}$ subject to the available production technology:

$$\max_{p_{j,t+s}} \quad \mathbb{E}_t \left[\sum_{s=0}^{\infty} (1-\theta)^s \lambda_{t,t+s} d_{j,t+s}\right] \tag{10}$$

$$\text{s.t} \quad y_{j,t+s} = a_{t+s} k_{j,t+s}^{\alpha} \ell_{j,t}^{1-\alpha}, \tag{11}$$

where $\lambda_{t,t+s}$ denotes the stochastic discount factor of the representative entrepreneur household, which owns all the intermediate-goods firms. The production function combines capital k_j and effective labour ℓ_j at productivity level a_t. The marginal rate of return of capital is given by α.

Policy and Shocks

Monetary policy is assumed to follow a Taylor-type rule (Taylor, 1993):

$$i_t = \bar{i} + \phi_p \Delta \log(p_t) + \phi_y \log(y_t/\hat{y}) + \varepsilon_t, \tag{12}$$

which states that the nominal interest rate is adjusted by the central bank around its steady-state level $\bar{i}$, in response to inflation $\Delta \log(p_t)$ and deviations of output y_t from its steady-state level $\hat{y}$, with respective intensities $\phi_p > 1$ and $\phi_y > 0$. The evolution of the nominal interest rate is subject to exogenous shocks ε_t which capture the non-systematic element of monetary policy, and are referred to as monetary policy shocks.

It is assumed that the government issues a constant real amount of debt B, whose service is financed by means of the receipts of the labour-income tax τ_t, which yields the government budget constraint:

$$\frac{1 + i_{t-1}}{\pi_t} B = B + \tau_t w_t \left[\int_0^{\eta} s_{h,t} n_{h,t} dh + \bar{s} n_t\right]. \tag{13}$$

It should be noted that the assumption that government debt issuance is constant in real terms, does not imply that households's proportional holdings of government bonds will decline as households accumulate savings, since in aggregate the stock of government debt grows in line with the real growth of the economy.

Moreover, the fact that the amount of debt issuance is fixed in real terms implies that the labour-income tax rate will evolve countercyclically. This means that fiscal policy will in general exacerbate cyclical fluctuations. This is in line with the evidence for Mexico where, with few exceptions, fiscal policy has been markedly procyclical, adopting a contractionary stance during downturns, and an expansionary stance during booms (Moreno and Villarreal, 2014).

In addition to idiosyncratic productivity shocks faced by entrepreneur households, and aggregate monetary policy shocks, the dynamics of the model economy are driven by two additional types of aggregate shocks: productivity and markup shocks. All aggregate shocks are assumed to follow stationary first-order autoregressive processes.

Equilibrium

The equilibrium for this economy is given by the vectors of aggregate quantities $(y_t, k_t, c_t, n_t, b_{t+1}, d_t)$ and prices (p_t, w_t, r_t); worker households' decision rules $(c_{h,t}(b,s), n_{h,t}(b,s))$ which in the presence of heterogeneity depend on their wealth, as measured by their bond-holdings $b_{h,t}$ and the realisation of the idiosyncratic productivity shock $s_{h,t}$; a distribution of households $\Gamma(b,s)$ over wealth and individual productivity levels; firm-level quantities[14] $(y_{j,t}, k_{h,t}, \ell_{j,t}, d_{j,t})$ and prices $(p_{j,t})$; and government policy functions such that:

1. Households solve their respective utility maximization problems as described in Section 4.1
2. The distribution of households over wealth and individual productivity levels is consistent with their decision rules and idiosyncratic shocks.
3. Firms solve their respective optimisation problems as described in Section 4.1
4. Monetary policy is conducted as described by equation (12)
5. Fiscal policy is conducted subject to the budget constraint (13)
6. The labour, capital and bonds markets clear:

$$\int_0^1 \ell_{j,t} dj = \int_0^\eta s_{h,t} n_{h,t} dh + \bar{s} n_t \tag{14}$$

$$k_t = \int_0^1 k_{j,t} dj \tag{15}$$

$$B = \int_0^\eta b_{h,t} dh + b_t \tag{16}$$

[14] As defined in equation (14), $\ell_{j,t}$ denotes firm j's skill-weighted demand for labour.

The model just described contains both the standard representative-agent New-Keynesian model, and the heterogeneous-agent New-Keynesian model as special cases. The former is obtained by setting parameter η equal to zero, while the latter is obtained by allowing all households to own capital and precluding trade in state-contingent securities.[15]

4.2 Solution and Model Properties

The main challenge in solving the model just described is that the state vector includes the distribution of wealth across households $\Gamma(b, s)$, which under the assumption of a continuum of heterogeneous agents is an infinite-dimensional object. The most widely used method to solve this class of models was developed by Krusell and Smith (1998). The procedure, known as approximate aggregation, reduces the dimensionality of the state-space by summarising the wealth distribution by means of a finite, and relatively small, set of moments. Since the interest of this investigation lies on the relationship between monetary policy and the heterogeneity of households, a richer characterisation is utilised. Instead, the solution method of Reiter (2009), which approximates the distribution by means of a histogram, is employed.

Calibration

Considering that the wealth distribution is a state variable of the model, and that the interest of the paper is to examine the relationship between monetary policy and household heterogeneity, the calibration strategy aims to match the main features of the distribution of income and wealth in the steady-state for the case of Mexico at a quarterly frequency. To the extent possible, parameters are calibrated based on official data. The remaining parameters are calibrated using estimates found in the literature. Table 2 summarises the parameter calibration values used in the baseline case.

Household preferences. The first panel summarises the parameters which determine the behaviour of households. The discount factor for entrepreneur households β is calibrated to match the average ex-post real interest rate of 2% observed over the period 2001–2014 (Banxico, 2016). The discount factor for worker households $\tilde{\beta}$ was chosen to match the general distribution of capital income accrued to each quintile.[16]

[15] Under the heterogenous-agent model specification all households would solve the following optimisation problem:

$$\max_{\{c_{h,t}\},\{n_{h,t}\},\{k_{h,t+1}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log c_{h,t} - \varphi_1 \frac{n_{h,t}^{1+\varphi_2}}{1+\varphi_2} \right]$$

$$\text{s.t} \quad p_t[c_{h,t} + k_{h,t+1}] + \Delta b_{h,t+1} = p_t \left[(i_{t-1}/p_t) b_{h,t} + d_{h,t} + (1-\tau_t) w_t s_{h,t} n_{h,t} + (1+r_t) k_{h,t} - \frac{\zeta}{2} \left(\frac{\Delta k_{h,t+1}}{k_{h,t}} \right)^2 k_{h,t} \right].$$

[16] In the absence of official estimates for the wealth distribution, the strategy relies on the assumption that the distribution of wealth is proportional to the distribution of income accruing from the ownership of capital as reported in the 2014 households' income and expenditure survey INEGI (2015a).

Table 2

Parameter calibration: Baseline case.

Parameter	Description	Value	Target / Source
I – Household preferences			
β	Entrepreneurs' discount factor	0.9950	Average ex-post real interest rate
$\tilde{\beta}$	Workers' discount factor	0.9947	Capital income of top quintile
φ_1	Relative willingness to work	38.0000	Average hours worked
φ_2	Inverse of labour supply elasticity	2.8571	Literature estimates
II – Household heterogeneity			
η	Measure of worker households	4.0000	Business income of top quintile
$\overline{s}$	Average entrepreneur households' productivity	1.7900	Labour and capital income of top quintile
$\Pi_{s,s'}$	Skill transition probability matrix	See Table 3	Labour survey
s_1	Low-skilled productivity	0.7264	Median labour-income of informally employed workers
s_2	Middle-skilled productivity	1.2499	Median labour-income of employers and own-account workers
s_3	High-skilled productivity	1.3701	Median labour-income of formally employed workers
III – Firms			
θ	Calvo price stickiness	0.3333	Average price duration
μ	Markup	1.3000	Average manufacturing markup
α	Coefficient of capital in production	0.3500	Production function estimate
δ	Capital depreciation rate	0.0166	Average aggregate depreciation rate
ζ	Capital adjustment cost	15.0000	Standard deviation of private investment
ξ	Fixed production cost	0.3188	Dividends/GDP
IV – Policy			
τ	Labour-income tax	0.0443	Average income tax revenue
ϕ_p	Policy responsiveness to inflation	1.2400	Best (2013)
ϕ_y	Policy responsiveness to output	0.0000	McKay and Reis (2016)
V – Economic structure			
ρ_μ	Autocorrelation of markup shock	0.4600	Best (2013)
σ_μ	Std. dev. of markup shock	0.0349	Best (2013)
ρ_a	Autocorrelation of productivity shock	0.7900	Best (2013)
σ_a	Std. dev. of productivity shock	0.0090	Best (2013)
ρ_ε	Autocorrelation of monetary policy shock	0.6400	Best (2013)
σ_ε	Std. dev. of monetary policy shock	0.0080	Best (2013)

Regarding preferences with respect to labour supply, the parameter φ_1 is calibrated so that in steady-state, the average of hours worked in the model match the approximately 45 weekly hours reported in labour survey data (INEGI, 2007) over the period 2005–2015. While a value of 2 is generally assumed for parameter φ_2, implying a Frisch elasticity of 0.5, the empirical evidence for Mexico (Fajnzylber and Maloney, 2001; Martínez, 2012) points to a lower elasticity, reflecting the absence of meaningful means of insurance in case of unemployment. Moreover, recent work by Reichling and Whalen (2012) for the case of the United States points to an average estimate of 0.4. In view of this, and considering it is reasonable to assume that in the absence of significant unemployment insurance and limited financial inclusion, the supply of hours worked in Mexico should be less sensitive to changes in wages than in the United States, a Frisch elasticity of 0.35 is assumed. The elasticity implies a value of 2.8571 for parameter φ_2.

Household heterogeneity. Jointly with the difference between the discount factors of entrepreneur and worker households, the parameters in panel II influence the model economy's distribution of income and wealth.

The parameter η which determines the relative magnitude of the mass of worker households with respect to entrepreneur households, is calibrated to approximate the distribution of business ownership income which accrues to each wealth quintile. The value of average productivity of entrepreneur households $\overline{s}$ targets the proportion of capital and labour-income received by the top quintile in household survey data, which is approximately 55%.

In order to calibrate the worker households' possible skill levels and corresponding Markov transition matrix, wage data from the Mexican quarterly labour survey (INEGI, 2007) is used.[17]

Focusing on wages for individuals working aged 25-65 and employed full time, following Rodríguez-Oreggia (2007), median wages are computed for the following categories of workers: i) those employed informally, as proxied by not having access to social security; ii) (self-declared) employers and own-account workers; and iii) workers employed formally in the public or private sector.

Wages are computed on a quarterly basis for the sample spanning the period 2005.I through 2015.IV. The resulting median wages are normalised so that the average wage income equals one. The process yields the level estimates for parameters s_1, s_2 and s_3, which indicate that informally employed workers earn 73% of the average wage, while employers and own-account workers, and formally employed workers earn wages which are respectively 25% and 37% above the mean wage.

The transition probability matrix between the current s and future s' skill levels $\Pi_{s,s'}$ is computed non-parametrically from survey data. Inspection of Table 3 reveals that despite large probabilities of remaining in the same employment categories, particularly for employers and own-account workers, there is a significant probability of switching categories at any given moment. Moreover, for employers and own-account workers, as well as for formally employed workers, the odds of becoming and staying informally unemployed are very high.

[17] Survey data reports wage income in current prices. In order to compare data across time, wage data is converted into constant prices using consumer price data.

Table 3
Productivity transition matrix.

Current/Future skill	s'_1	s'_2	s'_3
s_1	0.6782	0.2251	0.0967
s_2	0.1500	0.8085	0.0415
s_3	0.2146	0.1409	0.6445

Note: The sub-indices denote informal workers (1), self-declared employers and own-account workers (2), and formal workers (3), respectively.
Source: Author based on household-level labour-income data from INEGI (2007).

Firms. Panel III groups the parameters which determine the supply-side of the economy. The inverse of parameter θ is the average frequency between price adjustments. Using data for the period 1992–2007 under a hybrid New-Keynesian Phillips curve framework, Ramos-Francia and Torres (2008) find that average price duration in Mexico was roughly three quarters, implying a parameter θ of 0.3333.

Regarding the markup, while Castañeda (2003) finds evidence of a decline in the average manufacturing markup as a consequence of increased competition in the aftermath of Mexico's entry into the North American Free Trade Agreement (NAFTA), it was still a sizeable 1.8 in the late 1990s. Moreover, López-Noria (2013) suggests that despite the initial decline in the mid 1990s, markups in the manufacturing sector had remained constant at a level of between 1.2 and 1.4 depending on the liberalisation schedule imposed by NAFTA. In view of this, the markup parameter μ is set to 1.3.

For the coefficient of capital in production α, a production function was estimated from industry-level data (INEGI, 2014) using the estimation method proposed by Ackerberg et al. (2015) over the period 1990–2014, which yields a parameter value of 0.35. For the case of the capital depreciation parameter δ, the average depreciation rate implied by the ratio of capital consumption to capital stock over the period 2003–2014 in national accounts data is used (INEGI, 2015b), which yields an estimate of 1.66% for quarterly depreciation.

The variable capital cost adjustment parameter ζ is calibrated to match the variance of (detrended) private investment observed in the national accounts data (INEGI, 2013). Considering the scale of own-account work in Mexico, the target for the fixed production cost parameter ξ is the ratio of dividends to GDP (INEGI, 2015b), resulting in a value of 0.3188.

Policy and aggregate shocks. For the policy parameters, which are detailed in panel IV, the income tax parameter τ is calibrated using the average income revenue (as a percentage of GDP) of the Mexican federal government for the period 1990–2015 (SHCP, 2016).

The value for the Taylor-rule policy parameters ϕ, as well as the values for the persistence ρ and standard deviation σ shock parameters, summarised in panel V, correspond to the posterior estimates of the benchmark model in Best (2013). Under the baseline scenario the policy parameter of output ϕ_y is set to zero since to reflect the adherence of Banco de Mexico to a strict inflation targeting regime (Banco de México, 2007).

Properties of the Model

Table 4 contrasts the distribution of income and wealth from the data, with the steady-state results from the model. The model approximates the income and wealth distribution observed in the data relatively well. The Gini coefficients for income and wealth found by the model are 0.4 and 0.72 respectively, which are roughly in line with conservative inequality estimates for Mexico.

Table 4
Income and wealth distribution by quintiles (proportion of total).

	Income		Wealth	
Wealth quintiles	Model	Data	Model	Data
I	6.5	3.1	1.0	0.7
II	11.0	7.9	2.1	2.7
III	13.0	13.1	3.1	3.9
IV	14.8	20.9	4.7	7.7
V	54.7	55.0	89.1	85.0

Note: The distribution of income from the data comprises labour and capital income, and excludes income from other sources not considered in the model, such as transfers and imputed rent. The distribution of wealth in the data refers to the proportion of capital income accrued to each quintile, which implicitly assumes is proportional to the wealth stock held by each quintile.

As emphasized by Kaplan and Violante (2022), a key feature of heterogeneous-agent models is their ability to approximate the dispersion of marginal propensities to consume (MPC) across the income distribution. The heterogeneity of MPCs is crucial in the determination of the redistribution channel through which monetary policy affects macroeconomic aggregates (Auclert, 2019; Kaplan et al., 2018).

Table 5 summarises the marginal propensities to consume implied by the model for the different worker groups across selected percentiles of the distribution, which are relatively low. In an evaluation of the impact of transfers on consumption among poor households in Mexico, Skoufias et al. (2008) estimate marginal propensities to consume in the range of 0.14 to 0.17.

The relatively low MPC estimates reflect the calibration's overestimation of available income in the first three deciles. The difficulty of obtaining higher estimates is that under the model's specification, there is a tradeoff in matching the levels of income of the lower quintiles and matching the level of wealth of the top decile.

Despite this, it can be seen that in general terms the marginal propensity to consume is highest for the lower skill level group, that is for the group of workers employed in the informal sector. Moreover the effect becomes more pronounced as wealth declines. This means that to the extent that monetary policy affects households disposable income, the magnitude of the response of poorer and less skilled households will be larger, highlighting a key redistributive propagation mechanism. Thus, the low MPC estimates imply that the findings reported below are on the conservative side.

Table 5
Marginal propensities to consume.

	Wealth percentile				
Skill level	10th.	25th.	50th.	75th.	90th.
s_1	0.039	0.020	0.012	0.009	0.007
s_2	0.018	0.013	0.010	0.008	0.007
s_3	0.018	0.012	0.009	0.008	0.007

Note: s_1 includes informally employed workers, s_2 includes employers and own-account workers, and s_3 includes workers employed formally in the public or private sector.

Turning to the dynamic properties of the model, Table 6 compares the standard deviation of the main aggregates in the model with the moments in the data. The model is able to capture the magnitude of fluctuations in both aggregate output and private investment, and while it captures the fact that private consumption is less volatile than output, it underestimates its magnitude. This could be reflecting the omission of certain features such as financial and intermediate input frictions which have been found to play an important role in fitting DSGE models to data from developing countries (García-Cicco, 2009).

Table 6
Standard deviation of economy aggregates.

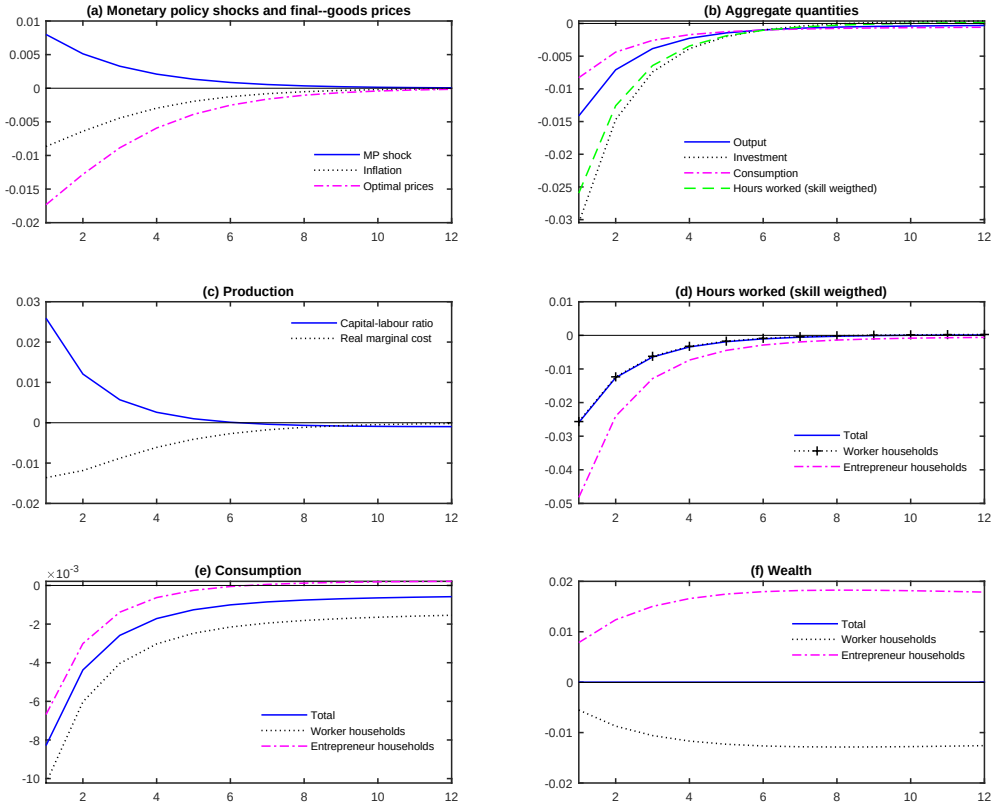
	Model	Data
Output	2.3636	2.6845
Private consumption	1.5341	2.2988
Private investment	4.8589	4.6101

Note: Aggregate data excludes public consumption and investment as they have no counterpart in the model. The standard deviations from the data are computed from the (log) level of detrended quarterly series for the period 2001.I–2015.IV. Trends were computed using the Hodrick-Prescott filter with a smoothing parameter of 1,600.

From the equation for the monetary policy Taylor rule (12) it can be verified that a positive monetary policy shock increases the nominal interest rate, which as shown in panel (a) of Figure 4 contemporaneously reduces the optimal prices chosen by price-adjusting firms, and thus overall current and expected inflation. In addition, as summarised in panel (b) the shock has a contractionary effect on the economy's main aggregates: consumption, investment and consequently output which in turn result in a reduction of hours worked. The effects, which are consistent with the findings in the literature (Cushman and Zha, 1997; Galí and Monacelli, 2005; Lubik and Schorfheide, 2007) dissipate over a 12-quarter horizon.[18]

A key finding is that the effects on consumption and leisure, from which households derive utility, are differentiated across households reflecting their heterogeneity with respect to the

[18]Impulse response functions measure deviations from the respective variable's steady-state level.



Note: Impulse response functions are normalised by the respective variables' steady-state values.

Figure 4. Impulse response functions: Baseline case.

risks they face, the availability of insurance mechanisms and their preferences. In particular, as a result of an unanticipated increase in the nominal interest rate, contemporaneous consumption is reduced by 1% for the case of worker households, whereas consumption of entrepreneur households is only reduced by 0.67%, thus exacerbating the model economy's inequality.

The differentiated effect operates through two channels (Auclert, 2019; Kaplan et al., 2018). The first occurs as households adjust their intertemporal consumption schedules in response to the direct effect of the monetary policy shock. The effect of an increase in the nominal interest rates and a reduction in anticipated inflation, leads households to substitute away from current consumption by making future consumption 'less costly'. However, considering that the lower discount factor of worker households implies a higher preference for current consumption, with respect to entrepreneur households, the effect is stronger on worker households (panel e of Figure 4).

The second channel operates through the general equilibrium effects of the monetary policy shock on households' disposable incomes. As a consequence of the fall in output and in the presence of costly capital adjustment costs, intermediate-goods producers use installed capital

more intensively to the detriment of labour demand. This results in the rise of the capital-ratio shown in panel (c) of Figure 4, and the fall of hours worked shown in panel (b). Since entrepreneur households are more productive than worker households, e.g. $\overline{s} > s_h \ \forall h$, and thus more costly to hire, the fall in their worked hours is steeper than that of worker households as shown in panel (d) of Figure 4.

Notwithstanding the larger reduction in hours worked, in contrast to worker households, entrepreneur households benefit from the general equilibrium effects of the monetary policy shock, to the extent that the rise in real interest rates implies additional flows from the ownership of capital. Moreover, as shown in panel (c) real marginal costs fall as a result of the positive monetary policy shock which, given the presence of sticky prices, implies that markups are countercyclical leading to additional revenue in the form of dividends from the ownership of firms. The combined effect is that the reduction of disposable income is more acute, and consequently the reduction on consumption more pronounced for the case of worker households, as illustrated in panel (e) of Figure 4.

Regarding wealth, as measured by real bond holdings, the incentive of higher interest rates for entrepreneur households is to unambiguously increase bond holdings. In contrast, for the case of worker households there are two opposing forces at work.

The first is to save more and take advantage from the higher yields. The magnitude of this effect is attenuated by the relative impatience of worker households which make it more costly to forego current consumption. The second force is that in the presence of uninsurable idiosyncratic risks, worker households have an incentive to save precautionarily.[19] In the case of an unanticipated increase of interest rates which leads to lower expected inflation, the precautionary motive is diminished leading to lower savings. As shown in panel (f) the net effect of the differentiated impact upon households' disposable incomes and the preference heterogeneity is that worker households actually reduce the proportion of government bonds held.

As discussed by Auclert (2019), and Kaplan et al. (2018), the differentiated effect of monetary policy on households' disposable income is the main channel through which monetary policy can influence household inequality.

4.3 Results

To explore the relationship between household heterogeneity and monetary policy, in this section two complementary sets of counterfactual experiments are conducted. In the first, the focus is on the effect of the design of monetary policy on inequality, while the second explores the feedback from household heterogeneity to the transmission of monetary policy.

The Effect of Monetary Policy on Households' Inequality

Under the baseline model specification, monetary policy is conducted according to the Taylor rule in equation (12) under the assumption that the central bank adheres to a strict inflation

[19] See, for example, Mengus and Pancrazi (2015) for a thorough discussion of the conditions under which the motive for precautionary savings arise.

targeting regime where $\phi_p > 1$ and $\phi_y = 0$. To examine the effect of policy responsiveness to inflation on inequality, the first experiment analyses the effects on the differentiated response of households' consumption and hours worked.

In the first scenario, monetary policy adjusts the nominal interest rate almost proportionally to inflation, i.e. $\phi_p = 1.01$. As discussed by Woodford (2003) the so-called Taylor principle states that, from a welfare perspective, in the traditional new Keynesian model, simple rules, such as the Taylor rule, can approximate optimal monetary policy by responding more than proportionally to inflation.[20] Thus, the assumption of proportionality is a useful benchmark since it represents borderline policy sub-optimality.

The second counterfactual assumes instead that policy responsiveness to inflation is more robust than under the baseline scenario ($\phi_p = 2.37$). Recall that the baseline value was obtained from Best (2013), which uses data up to 2005. Considering that monetary policy was very proactive as a response to the financial crisis of 2008–2009, the value used for the robust response counterfactual is obtained from an estimation of the model of Lubik and Schorfheide (2007) for Mexico with data from 2000.I through 2014.III.

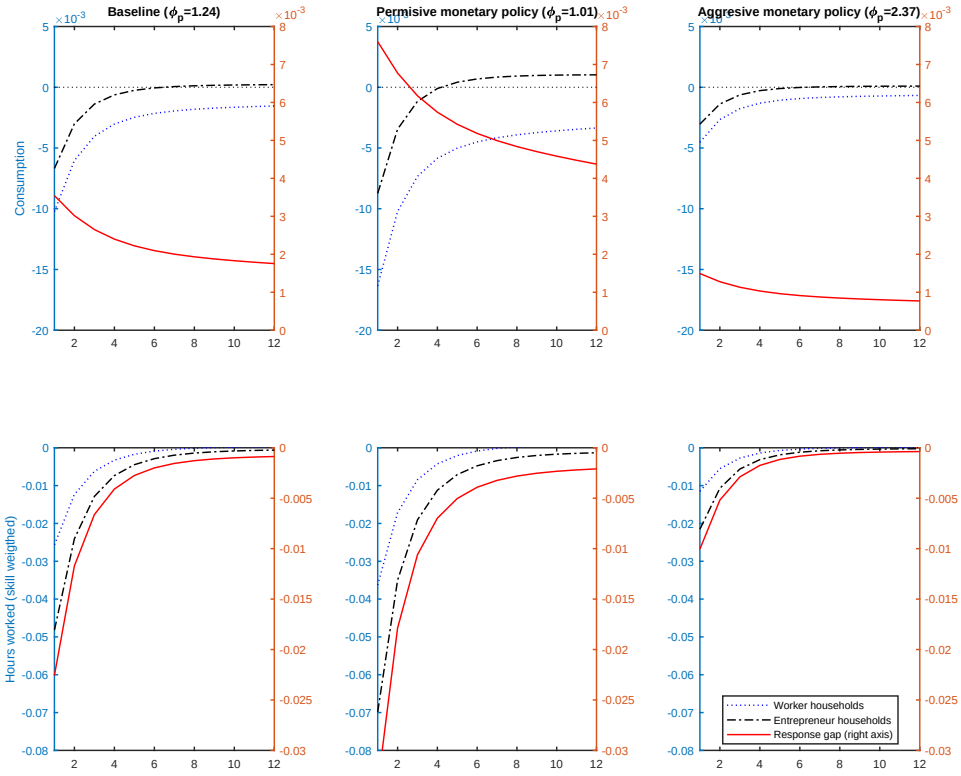
Policy responsiveness to inflation. Figure 5 plots the response function of households' consumption (top row) and labour (bottom row) to a monetary policy shock, as well as the gap between the responses of entrepreneur and worker households, under the baseline case and the two alternative scenarios. The responses of worker households are the sum of individual household's consumption and hours worked. In the case of hours worked the aggregation is weighted by the household's productivity level.

A positive value of the gap, measured of the right axis, such as the one observed in the top row for consumption responses, means that, as a result of an unanticipated increase in nominal interest rates, the fall in consumption of entrepreneur households is smaller than that of worker households, thus increasing aggregate inequality of consumption. In contrast, a negative value of the gap, such as the one observed in the bottom row for hours-worked responses, means that the reduction of hours worked for entrepreneur households is larger than the reduction observed for entrepreneur households.

As previously discussed, under the baseline case despite the larger relative reduction in hours worked by entrepreneur households, and corresponding fall in wage income, their lower discount factor and the additional income accruing from the ownership of capital attenuate the impact on their consumption, resulting in a smaller relative fall with respect to worker households' consumption. Since entrepreneur households are richer and have higher consumption levels in steady state, this means that inequality of consumption increases in response to a contractionary monetary policy shock.

The results in columns two and three of Figure 5 plot the responses that would be observed under the assumption of, respectively, a permissive and an aggressive monetary policy response to inflation. While it is clear that under strict inflation targeting, the response of consumption

[20] In fact, the equilibrium of this class of models becomes indeterminate when the response to inflation is exactly or less than proportional.



Note: The figure plots the impulse response functions of worker (dotted line) and entrepreneur (dashed line) households' consumption (top row) and skill-weighted hours worked (bottom row) to a monetary policy shock, as well as the gap (continuous line) between the responses, under three alternative assumptions regarding policy responsiveness. Positive (negative) values for the gap, which is measured off the right axis, indicate that the decrease in the respective variable for worker households is greater (lesser) than the one experienced by entrepreneur households.

Figure 5. Policy responsiveness to inflation.

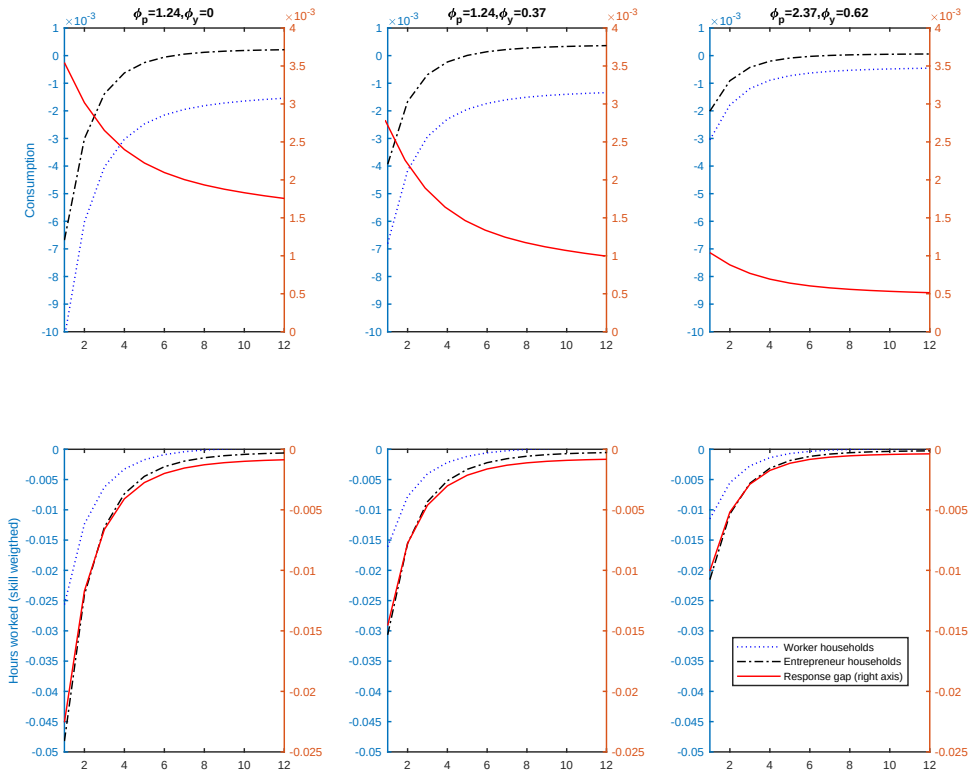
inequality remains countercyclical regardless of the responsiveness of policy to inflation, the magnitude of the reduction of consumption and hours worked for both types of households, as well as of the size of the gap between responses, is greater under a permissive response to inflation. This occurs because under a permissive policy response, the expectation of relatively higher levels of inflation gives rise to precautionary savings, which result in a steeper reduction of consumption, as well as an increase in its inequality reflecting the fact that the incentive for precautionary savings, and the marginal propensity to consume, is stronger for poorer households.

Output target. The second experiment examines the evolution of the response of consumption and hours worked under the assumption that, in addition to inflation, monetary policy targets deviations of output from its steady-state level. Two scenarios are considered. In the first scenario, the inflation policy parameter is kept at its baseline value and it is assumed that the output policy parameter takes the value of $\phi_y = 0.37$ which corresponds to the values estimated

by Best (2013). The second scenario uses the estimates stemming from the estimation of the model of Lubik and Schorfheide (2007) for Mexico, which are roughly double in magnitude to the parameter values under the first scenario.

As before, the first column of Figure 6 shows the response of consumption and hours worked under the baseline case, whereas the second column summarises the impact of introducing a target for output in the policy function. Finally, the third column illustrates the results that would be observed under a more aggressive policy response to both output deviations and inflation, than that considered in the second column.

Regarding the magnitude of the responses, as should be expected it is clear that introducing a target for output attenuates the impact on both consumption and hours worked, and that a more aggressive policy stance further reduces the size of household responses. Moreover, the speed with which variables return to their steady-state levels is faster when output is targeted, and when an aggressive policy stance is adopted. This occurs because forward-looking households



Note: The figure plots the impulse response functions of worker (dotted line) and entrepreneur (dashed line) households' consumption (top row) and skill-weighted hours worked (bottom row) to a monetary policy shock, as well as the gap (continuous line) between the responses, under three alternative assumptions regarding policy responsiveness. Positive (negative) values for the gap, which is measured off the right axis, indicate that the decrease in the respective variable for worker households is greater (lesser) than the one experienced by entrepreneur households.

Figure 6. Policy target.

anticipate smoother shocks over the business cycles as a result of the adoption of an explicit target for output, as well as of a firmer policy response to deviations from targets.

With respect to consumption inequality, contrasting the dynamics of consumption responses between the baseline case and the first scenario, shown in the top of the first and second columns of Figure 6, it can be seen that the introduction of a target for output not only reduces the size of the response, but also reduces the redistributive effect of monetary policy shocks. This reduction in both the size of household's responses, as well as in the gap between the responses across household types is more acute when an aggressive response is considered.

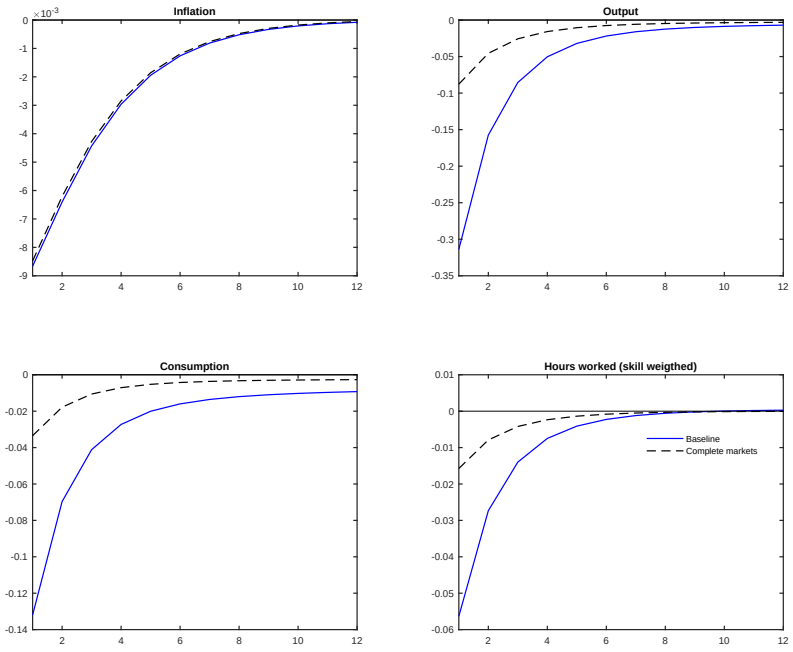
Heterogeneity and the Transmission of Monetary Policy

As discussed in Section 4 there are two features of the model which give rise to inequality across households: incomplete markets and preference heterogeneity. A natural benchmark to explore the impact of heterogeneity on the transmission of monetary policy is the case where markets are complete and all households have the same preferences. As discussed earlier, by assuming that the mass of worker households is equal to zero, i.e. $\eta = 0$ the model collapses to the traditional New-Keynesian monetary policy model with a single representative agent. Even though households still face idiosyncratic productivity risks, they can insure perfectly against them since they can trade in contingent securities.

Incomplete markets. Figure 7 compares the responses of inflation, aggregate output, aggregate consumption and total hours worked under the baseline case discussed in Section 4.2, with the responses that would be observed if markets were complete and household preferences were homogeneous. While qualitatively the response is similar under both cases, with all four aggregates falling as a response to unanticipated increases in the nominal interest rate; with the exception of inflation, under the assumption of complete markets, the magnitude of the contemporaneous effect is markedly smaller, and the period over which the shock effects dissipate shorter.

Results indicate that in comparison to the representative agent model, in the case of the model with incomplete markets and heterogeneous preferences, the "cost" in terms of the reduction in output in the latter case is over three times larger, and over four times larger in terms of the reduction in aggregate consumption.

The reason for this is that, as discussed above, the presence of uninsurable idiosyncratic risks gives rise to precautionary savings, which result in higher investment and a higher capital stock with respect to the levels that would be observed in the complete markets economy. Since returns to capital are assumed to have diminishing marginal returns, a higher capital stock means that with respect to the complete market economy, the real interest rate in the economy with uninsurable idiosyncratic risks will be lower and the wage rate relatively higher. As discussed by Dávila et al. (2012) this signifies that in the baseline case the uninsurable portion of households' income is larger than in the complete markets case, and thus the responses to shocks more pronounced.



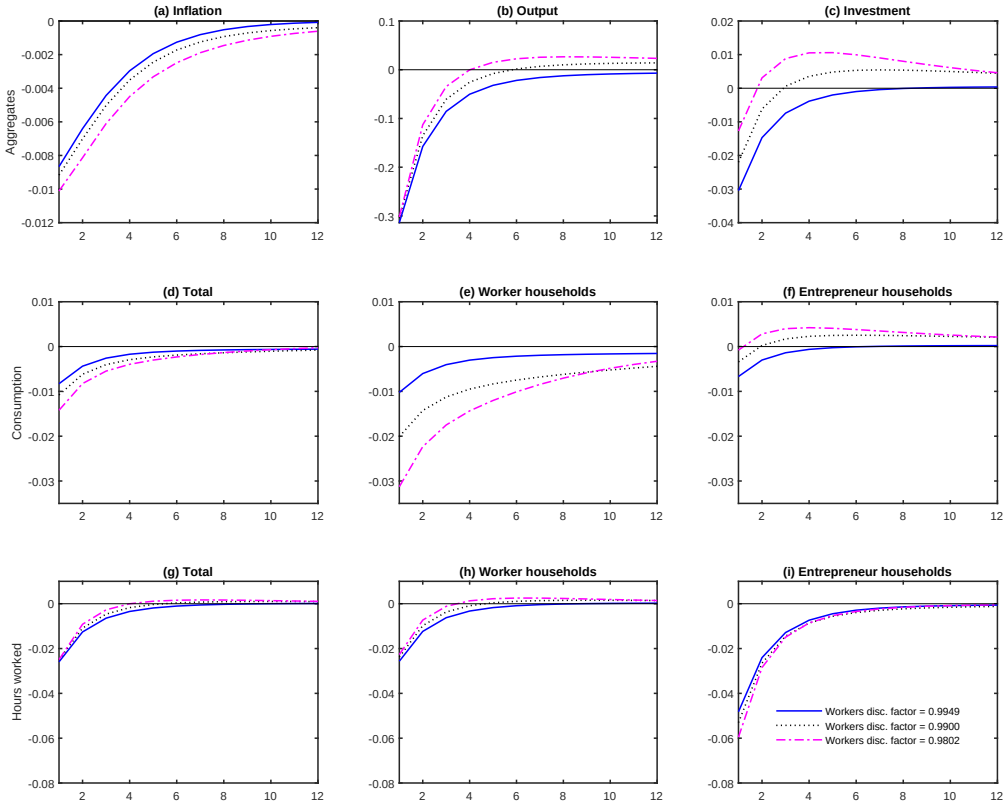
Note: The figure contrasts the response functions of selected model aggregates to a monetary policy shock under the baseline case (solid lines), with the response functions under the assumption that markets are complete and preferences homogeneous (dashed lines).

Figure 7. Complete markets and homogeneous preferences.

Preference heterogeneity. Part of the effect found under the complete markets counterfactual is the result of the imposition of preference homogeneity. To investigate the role of preference heterogeneity, the last experiment evaluates the impact of changes in the discount rate of worker households while keeping the baseline specification of incomplete markets. The results are shown in Figure 8.

As shown in panel (a) of Figure 8, a lower discount factor implies a sharper reduction in inflation in response to a contractionary monetary policy shock. This occurs because lowering the worker households' discount factor is equivalent to rising their marginal propensity to consume. Thus, in response to a given fall in disposable income, as shown in panel (e) worker households reduce their consumption more acutely, leading to a steeper fall in aggregate consumption (see panel d), and thus inflation falls further.

In an attempt to smooth consumption, worker households increase their labour supply, shown in panel (h), which through its effect on relative factor prices, causes a larger reduction of marginal costs. Since the lower marginal costs imply higher markups, the result is to attenuate the impact on entrepreneur households' consumption and investment, illustrated in panels (f) and (c) respectively. In fact, as shown in the figure, for sufficiently low levels of the worker households' discount factor, entrepreneur households' consumption and investment actually rise as a response of an unanticipated increase in the nominal interest rate.



Note: The top row of the figure plot the responses of inflation, output and investment to a contractionary monetary policy shock under alternative assumptions regarding the value of the worker households' discount factor. The first column of the second and third row plot, respectively, the impulse response functions of total consumption and skill-weighted worked hours, while the differentiated responses by household type are plotted in the remaining columns.

Figure 8. Preference heterogeneity.

The contrasting dynamics of the responses by worker and entrepreneur households explain why the contemporaneous effect of a monetary policy shock on aggregate output, plotted in panel (b), is of a similar magnitude under alternative value for the worker households' discount factor. The faster return of both hours worked and output to their steady state levels with lower discount factors, reflects the fact that poorer households become more responsive to increases in disposable income.

In summary, the presence of uninsurable idiosyncratic shocks not only affects the response of the economy's aggregates to unanticipated increases in the nominal interest rate, but also exacerbates the already sizeable levels of inequality that characterise the model economy. Moreover, the magnitude of the effect on inequality appears to be larger the more unequal initial conditions are.

5. Conclusions

The paper contributes to the emerging literature exploring the distributive consequences of monetary policy, by using a dynamic stochastic general equilibrium model with heterogenous agents which can not insure themselves against idiosyncratic risks because markets are incomplete, to explore the relationship between monetary policy and household inequality for the case of Mexico.

First, the paper empirically investigates the impact of monetary policy on the distribution of household labour-income for the case of Mexico. The results suggest that an unanticipated increases of 80 basis points in the nominal interest rate, cause an increase of 0.12 in the Gini coefficient of households' labour income inequality.

Motivated by the empirical findings, the paper then proceeds to examine the transmission channels by calibrating a Heterogeneous Agent New Keynesian Dynamic Stochastic General Equilibrium model for Mexico. The model captures three key features of the Mexican economy: i) High level of heterogeneity that characterizes the distribution of income and wealth across households; ii) limited availability of mechanisms to insure against the occurrence of shocks that affect labour income; and iii) the model's policy blocks includes the conduction of monetary policy under an inflation targeting regime, as well as a procyclical fiscal policy.

Under the base calibration, which successfully approximates the main features of the business cycle and the distribution of household income and wealth, the results indicate that the main channel through which monetary policy affects the distribution of income and wealth across households, is through a differentiated effect on the different streams that constitute households' disposable income.

As a result of an unanticipated increase in the nominal interest rate, which leads to a fall in aggregate inflation and output, worker households, whose main source of income is that coming from labour, must contemporaneously reduce their consumption by 1%, whereas entrepreneur households' consumption is only reduced by 0.67%. This reflects entrepreneur households ability to limit the fall in their consumption levels by the additional income resulting from the effect of the shock on business and capital ownership income.

The lack of access to trade in contingent liabilities gives rise to precautionary savings by worker households who cannot insure themselves against idiosyncratic risk. Precautionary savings, however, are suboptimal to the extent that through the effect on factor shares and prices, the proportion of aggregate income that is subject to uninsurable risk increases, thus exacerbating the negative impact of contractionary monetary policy shocks on output, labour and consumption; as well as on their distribution across households. Results indicate that while the reduction of inflation is similar under the assumptions of incomplete markets and heterogeneous preferences, and the assumptions of a representative agent model, the contraction in output is over three times larger, and the contraction in consumption is over four times larger, in the case of incomplete markets and heterogeneous preferences.

The findings also suggest that a Taylor-type rule which aggressively targets both inflation and deviations of output from its steady state level, can ameliorate the impact of monetary policy

on households' income and consumption levels as well as on the resulting inequality.

In terms of public policy, the results suggests that the impact of monetary policy on households' labour-income inequality could be attenuated by three sets of policies. The first concerns the availability of unemployment insurance, which could afford workers to search for employment within the formal sector, instead of migrating to the informal sector as a response to unemployment. The second set is related to policies aimed at reducing the size of both informal employment, which to a large extent reflect distortions introduced by labour regulations (Levy, 2008), as well as the informal sector, which mainly reflect the incentives created by the design and implementation of tax policies. The third set of policies are related to a financial inclusion strategy which enhances the set of tools which households can use to insure themselves against risk.

Appendix

Households' Labour-Income Data

Considering the time frame in which monetary policy shocks propagate through the economy, it is necessary to use data at sub-annual frequencies. With this in mind, households' income inequality is measured using labour income drawn from the Mexican labour force survey, which is available on a quarterly basis, instead of the biennial income and expenditure survey.

The data set contains observations from the first quarter of 2001 through the third quarter of 2014.[21] The start date was chosen to coincide with the adoption of an inflation targeting regime by the monetary authorities in Mexico.

The observations from the period 2001.I through 2004.IV are drawn from the National Urban Employment Survey (ENEU) (INEGI, 2001), while the data corresponding to the period 2005.I through 2014.III, come from the National Survey of Labour and Employment (ENOE) (INEGI, 2007). Since the ENEU survey is only representative at the urban level, in order to splice the data from both surveys, observations from the ENOE survey are restricted to those corresponding to urban areas which were persistently surveyed over the period 2001–2014.[22,23]

At the individual level, labour income is computed for workers aged 25-65 who are regular residents of the household surveyed, that worked a positive number of hours during the week previous to the survey, and that do not report working on the street in exchange for tips, as the activity is not considered employment for official figures. In order to reduce the bias introduced by extreme observations, the sample is further restricted to those individuals which report real hourly wages of less than 2,000 pesos (approximately 165 United States' Dollars at 2010 prices).

At the household level, labour-income includes income by all household members who are older than 14 years of age. However, for the computation of summary statistics only households whose head is aged between 25 and 65 are considered. To account for economies of scale within households, the focus is on *equivalized household income*, which is calculated by adjusting each household member's labour income by a factor of 1 for the household head, and 0.5 for individuals of at least 14 years of age.[24]

Individual hourly wages are obtained by dividing the reported monthly income over the product of reported weekly hours worked times a factor of 4.33 to account for average weeks in any given month. All nominal income measures are deflated using the consumer price index with base corresponding to the second fortnight of December 2010.

All summary measures are computed using survey sampling weights. In the case of hourly wages, the weights used are the product of sampling weights times weekly hours worked.

[21] Only data up to the third quarter of 2014 was used because as a result of the constitutional reform that increased the minimum working age from 14 to 15 years of age, the most recent survey waves are not directly comparable to those corresponding to quarters before 2004.IV

[22] The urban areas included are: Mexico City, Guadalajara, Monterrey, Puebla, León, San Luis Potosí, Mérida, Chihuahua, Tampico, Veracruz, Acapulco, Aguascalientes, Morelia, Toluca, Saltillo, Villahermosa, Tijuana, Culiacán, Hermosillo, Durango, Tepic, Campeche, Cuernavaca, Oaxaca, Zacatecas, Colima, Querétaro and Tlaxcala.

[23] The splicing algorithm is partially based on the procedure used by Alcaraz and Nakashima (2013)

[24] The scale was originally proposed by Hagenaars et al. (1994) and subsequently adopted by the Statistical Office of the European Union (EUROSTAT).

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