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Monetary Policy and the Redistribution Channel†

By Adrien Auclert*

This paper evaluates the role of redistribution in the transmission mechanism of monetary policy to consumption. Three channels affect aggregate spending when winners and losers have different marginal propensities to consume: an earnings heterogeneity channel from unequal income gains, a Fisher channel from unexpected inflation, and an interest rate exposure channel from real interest rate changes. Sufficient statistics from Italian and US data suggest that all three channels are likely to amplify the effects of monetary policy. (*JEL* E21, E31, E43, E52)

There is a conventional view that redistribution is a side effect of monetary policy changes, separate from the issue of aggregate stabilization which these changes aim to achieve. Most models of the monetary policy transmission mechanism implicitly adopt this view by featuring a representative agent. By contrast, in this paper I argue that redistribution is a *channel* through which monetary policy affects macroeconomic aggregates, because those who gain from accommodative monetary policy have higher marginal propensities to consume (MPCs) than those who lose. The simple argument goes back to Tobin (1982, p.10):

> *Aggregation would not matter if we could be sure that the marginal propensities to spend from wealth were the same for creditors and for debtors. But* [...] *the population is not distributed between debtors and creditors randomly. Debtors have borrowed for good reasons, most of which indicate a high marginal propensity to spend from wealth or from current income.*

In this paper, I use consumer theory to refine Tobin's intuitions about aggregation. My analysis clarifies who gains and who loses from monetary policy changes, as well as the effect on aggregate consumption. Monetary expansions tend to increase real

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incomes, to raise inflation and to lower real interest rates. Not everyone is equally affected by these changes. This generates three distinct sources of redistribution.

First, monetary expansions increase labor and profit earnings. The distribution of these gains is unlikely to be equal: some agents tend to benefit disproportionately, and conversely, some tend to lose in relative terms. This is the *earnings heterogeneity channel* of monetary policy.

Second, unexpected inflation revalues nominal balance sheets, with nominal creditors losing and nominal debtors gaining: this is the *Fisher channel*, which has a long history in the literature since Fisher (1933). This channel has been explored by Doepke and Schneider (2006), who measure the balance sheet exposures of various sectors and groups of households in the United States to different inflation scenarios. Net nominal positions (NNPs) quantify the exposures to unexpected increases in the price level.

Real interest rate falls create a third, more subtle form of redistribution. These falls increase financial asset prices. But it is incorrect to claim that asset holders generally benefit: instead, we have to consider whether their assets have longer durations than their liabilities. Importantly, liabilities include consumption plans, and assets include human capital. Unhedged interest rate exposures (UREs), the difference between all maturing assets and liabilities at a point in time, are the correct measure of households' balance-sheet exposures to real interest rate changes, just like net nominal positions are for price-level changes. For example, agents whose financial wealth is primarily invested in short-term certificates of deposit tend to have positive UREs, while those with large long-term bond investments or adjustable-rate mortgage liabilities tend to have negative UREs. Real interest rate falls redistribute away from the first group toward the second group: this is what I call the *interest rate exposure channel*.

In this paper, I show how these three redistribution channels affect the transmission mechanism of monetary policy to consumption. My main theoretical result decomposes the consumption effect of a transitory change in monetary policy into a contribution from each of these channels, together with an *aggregate income* and a *substitution channel*. Representative-agent models only feature the latter two. My theorem shows that redistribution amplifies these effects, provided that winners from monetary expansions have higher MPCs than losers. The rest of the paper argues that this appears to be the case in the data. In brief, the redistributive effects of monetary policy are important to understand its aggregate effects.[1]

In the first part of the paper, I establish my main decomposition by studying a general aggregation problem. In partial equilibrium, I consider an optimizing agent with a given initial balance sheet, who values nondurable consumption and leisure, and is subject to a transitory change in income, inflation, and the real interest rate. I

[1] My theorem applies to a broad class of general equilibrium models with heterogeneous agents, so it can be used to understand consumption in other contexts than that of monetary policy. At the same time, I am leaving a number of redistributive channels out of my analysis. First, I abstract away from aggregate risk, so cannot handle changes in risk premia, as in Brunnermeier and Sannikov (2016). Second, I do not model limited participation, so monetary policy cannot differentially affect participants and nonparticipants, as in the studies of Grossman and Weiss (1983), Rotemberg (1984), and others. Finally, since I assume that all assets are remunerated at the risk-free rate, my analysis does not address the unequal incidence of inflation due to larger cash holdings by the poor (Erosa and Ventura 2002, Albanesi 2007). These are all interesting dimensions along which the theory could be extended.

decompose his consumption response into a substitution effect and a wealth effect, and show that the latter is the product of his MPC out of income and a balance-sheet revaluation term in which NNPs and UREs appear. This result is robust to the presence of durable goods, incomplete markets, idiosyncratic risk, and (certain kinds of) borrowing constraints. In other words, the MPC out of a windfall income transfer is a key determinant of the response of optimizing consumers to inflation (or real interest rate) induced changes in their balance sheets. This result generalizes previous findings by Kimball (1990) on the importance of MPCs in incomplete-markets consumption models.

I then aggregate these individual-level predictions and exploit the fact that financial assets and liabilities net out in general equilibrium to obtain the first-order response of aggregate consumption to simultaneous transitory shocks to output, inflation, and the real interest rate. This response is the sum of five terms, reflecting the contributions from the two aggregate and the three redistributive channels mentioned above. Moreover, the magnitudes of the redistributive channels are given by sufficient statistics: the cross-sectional covariances between MPCs and exposures to each aggregate shock. Since the pioneering work of Harberger (1964), sufficient statistics have been used in public finance to evaluate the welfare effect of hypothetical policy changes in a way that is robust to the specifics of the underlying structural model (see Chetty 2009 for a survey). Mine are useful to evaluate the impact of hypothetical changes in macroeconomic aggregates on *aggregate consumption* in a similarly robust way. All that is required is information on household balance sheets, income and consumption levels, and their MPCs.

By further assuming that the elasticity of intertemporal substitution σ and the elasticity of relative income to aggregate income γ are constant in the population, I obtain a set of five estimable moments that summarize all we need to know about agents' heterogeneity to recover the aggregate elasticities of consumption to the real interest rate, the price level, and aggregate income. Contrary to σ (and perhaps γ), these sufficient statistics are not structural parameters: they are likely to vary over time and across countries.[2] I set out to measure them in three separate surveys, covering different time periods, countries, and methods from the literature. I use a 2010 Italian survey containing a self-reported measure of MPC (Jappelli and Pistaferri 2014); the 1999–2013 waves of the US Panel Survey of Income Dynamics, together with semi-structural approach to identify the MPC out of transitory income shocks (Blundell, Pistaferri, and Preston 2008); and the 2001–2002 waves of the US Consumer Expenditure Survey, together with a method that exploits the randomized timing of tax rebates as a source of identification for MPC (Johnson, Parker, and Souleles 2006).

Consider first the elasticity of consumption to the real interest rate. In a representative-agent world, this elasticity is due to intertemporal substitution. It is negative, and its magnitude depends on σ. I define a method for measuring UREs, and show that, in each of my three datasets, their covariance with MPCs is also negative. Through the lens of my theorem, this implies that the interest rate exposure

[2] For example, typical incomplete market models imply that they should vary over time, as aggregate shocks affect the extent to which households' borrowing limits are binding, and that they should vary across countries depending on the maturity structure of financial contracts and the degree to which contracts are indexed to inflation.

channel acts in the same direction as the substitution channel, and with comparable magnitude provided that σ is between 0.1 and 0.4. Hence, representative-agent analyses that abstract from redistribution may fail to capture an important reason why real interest rates affect consumption, especially if σ is small.[3]

Similarly, across datasets, the covariance between MPCs and NNPs is negative on average. This implies that consumption tends to increase with inflation as a result of the Fisher channel. However, when cast in terms of elasticities, the magnitude is small: an unexpected 1 percent permanent increase in the price level raises consumption today by no more than 0.1 percent. This suggests that, while changes in monetary policy can entail significant nominal redistribution, the aggregate effect of this redistribution on consumption is likely to be modest.

Finally, in line with previous literature, I estimate the covariance between MPCs and incomes to be negative in the data. If, in addition, low-income agents disproportionately benefit from increases in aggregate income, as suggested, for example, by Coibion et al. (2017), the earnings heterogeneity channel also amplifies the effects of monetary policy.

Future work can build on these empirical results in two ways: by providing more precise measures of exposures across groups of agents or regions to inform the debate on the winners and losers from changes in monetary policy, and by estimating the sufficient statistics more precisely in administrative data to help quantify the aggregate effect of this redistribution.[4]

A rapidly growing literature analyzes the effects of monetary policy in dynamic stochastic general equilibrium models with rich heterogeneity, matching various aspects of the cross section such as the wealth distribution. Prominent examples include Gornemann, Kuester, and Nakajima (2016); McKay, Nakamura, and Steinsson (2016); and Kaplan, Moll, and Violante (2018). These structural models overcome a number of important limitations of my sufficient statistics approach. They can study the role of investment, analyze the precise interaction between monetary and fiscal policy, and explore the effect of shocks that are persistent and/or announced in advance. My paper makes two contributions to this literature. First, I introduce a decomposition of the monetary policy transmission mechanism into its various sources of effects on consumption that is useful to shed light on the underlying mechanisms in any such model (see Kaplan, Moll, and Violante 2018 for an influential application). Second, I argue that sufficient statistics can discipline the construction of these models. By making sure that the model's sufficient statistics match the data, researchers can ensure that, even if the model is misspecified, its predictions for the response of consumption to shocks are consistent with the empirical evidence.

This paper is motivated by an extensive empirical literature documenting that MPCs are large and heterogeneous in the population (see Jappelli and Pistaferri 2010

[3] Macroeconomists tend to assume that σ is around 0.5 (see, e.g., Hall 1988 or Havránek 2015). By contrast, financial economists tend to assume values around 2 (see, e.g., Bansal, Kiku, and Yaron 2016). If σ is large, the substitution effect plays a dominant role in the overall consumption elasticity.

[4] See Tzamourani (2018) for a quantification of unhedged interest rate exposures in the euro area, and Fagereng, Holm, and Natvik (2018) for estimates of sufficient statistics using Norwegian administrative data and the MPCs of lottery winners. The results in both papers are broadly consistent with mine.

for a survey), and that they depend on household balance sheet positions.[5] Recently, Di Maggio et al. (2017) have measured the consumption response of households to changes in the interest rates they pay on their mortgages. My theory shows that their paper quantifies an important leg of the redistribution channel of monetary policy.

Several papers have focused on the redistributive channels of monetary policy I highlight in isolation. Coibion et al. (2017) propose an empirical evaluation of the earnings heterogeneity channel by measuring how identified monetary policy shocks affect income inequality in the Consumer Expenditure Survey. The Fisher channel has received a great deal of attention in the literature following the work of Doepke and Schneider (2006). For example, on the normative side, Sheedy (2014) asks when the central bank should exploit its influence on the price level to ameliorate market incompleteness over the business cycle. On the positive side, Sterk and Tenreyro (2018) show that the Fisher channel can be a source of effects of monetary policy under flexible prices in a non-Ricardian model. The interest rate exposure channel has, by contrast, not received much attention in the context of monetary policy.[6]

The importance of MPC differences in the determination of aggregate demand is well understood by the theoretical literature on fiscal transfers.[7] MPC differences between borrowers and savers, in particular, have been explored as a source of aggregate effects from shocks to asset prices or to borrowing constraints.[8] In Farhi and Werning (2016b), MPCs enter as sufficient statistics for optimal macro-prudential interventions under nominal rigidities. None of these studies, however, focus on the role of MPC differences in generating aggregate effects of monetary policy.

The remainder of the paper is structured as follows. Section I presents a partial equilibrium decomposition of consumption responses to shocks into substitution and wealth effects. Section II provides my aggregation result and discusses the monetary policy transmission mechanism with and without heterogeneity. Section III contains my measurement exercise. Section IV concludes.

I. Household Balance Sheets and Wealth Effects

In this section, I show how households' balance sheets shape their consumption and labor supply adjustments to a transitory macroeconomic shock. I first highlight the forces at play in a life-cycle labor supply model (Modigliani and Brumberg 1954, Heckman 1974) featuring perfect foresight and balance sheets with an arbitrary maturity structure. Balance sheet revaluations and marginal propensities to consume and work play a crucial role in determining both the welfare and the wealth effects of the shock (Theorem 1). Under certain conditions, the positive results from Theorem 1 survive the addition of idiosyncratic income uncertainty (Theorem 2) and therefore apply to a large class of microfounded models of consumption behavior.

[5] See, for example, Mian, Rao, and Sufi (2013); Mian and Sufi (2014); Baker (2018); Jappelli and Pistaferri (2014); and Cloyne, Ferreira, and Surico (forthcoming).

[6] Redistribution through real interest rates does play a prominent role, for example, in Bassetto's (2014) study of optimal fiscal policy or in Costinot, Lorenzoni, and Werning's (2014) study of dynamic terms of trade manipulation.

[7] See Galí, López-Salido, and Vallés (2007); Oh and Reis (2012); Farhi and Werning (2016a); and McKay and Reis (2016).

[8] See King (1994), Eggertsson and Krugman (2012), Guerrieri and Lorenzoni (2017), and Korinek and Simsek (2016).

A. *Perfect-Foresight Model*

Consider a household with separable preferences over nondurable consumption $\{c_t\}$ and hours of work $\{n_t\}$.[9] I assume no uncertainty for simplicity: the same insights obtain when markets are complete, except with respect to the unanticipated initial shock. The household is endowed with a stream of real unearned income $\{y_t\}$. He has perfect foresight over the general level of prices $\{P_t\}$ and the path of his nominal wages $\{W_t\}$, and holds long-term nominal and real contracts. Time is discrete, but the horizon may be finite or infinite, so I do not specify it in the summations. The agent solves the following utility maximization problem:

$$\max \sum_t \beta^t \{u(c_t) - v(n_t)\} \tag{1}$$

subject to

$$P_t c_t = P_t y_t + W_t n_t + ({}_{t-1}B_t) + \sum_{s \geq 1} ({}_tQ_{t+s})({}_{t-1}B_{t+s} - {}_tB_{t+s})$$
$$+ P_t({}_{t-1}b_t) + \sum_{s \geq 1} ({}_tq_{t+s}) P_{t+s}({}_{t-1}b_{t+s} - {}_tb_{t+s}).$$

The flow budget constraint (1) views the consumer, in every period t, as having a portfolio of zero coupon bonds inherited from period $t-1$, and determining consumption c_t, labor supply n_t, as well as a portfolio of bonds to carry into the next period.[10] Specifically, ${}_tQ_{t+s}$ is the time-t price of a nominal zero-coupon bond paying at $t+s$, ${}_tq_{t+s}$ the price of a real zero-coupon bond, and ${}_tB_{t+s}$ (respectively ${}_tb_{t+s}$) denote the quantities purchased. This asset structure is the most general one that can be written for this dynamic environment with no uncertainty. To keep the problem well-defined, I assume that the prices of nominal and real bonds prevent arbitrage profits. This implies a Fisher equation for the nominal term structure:

$${}_tQ_{t+s} = ({}_tq_{t+s}) \frac{P_t}{P_{t+s}}, \quad \forall t, s.$$

I focus on the period $t = 0$. The environment allows for a very rich description of the household's initial holdings of financial assets, denoted by the consolidated claims, nominal $\{{}_{-1}B_t\}_{t \geq 0}$ and real $\{{}_{-1}b_t\}_{t \geq 0}$, due in each period. The former could represent deposits, long-term bonds and most typical mortgages. The latter could represent stocks (which here pay a riskless real dividend stream and therefore are priced according to the risk-free discounted value of this stream), inflation-indexed government bonds, and price-level adjusted mortgages. I write the real wage at t as $w_t \equiv W_t/P_t$, the initial real term structure as $q_t \equiv {}_0q_t$, the initial nominal term structure as $Q_t \equiv {}_0Q_t$, and impose the present-value normalization $q_0 = Q_0 = 1$.

[9] I present results for separable preferences because expressions for substitution elasticities take simple and familiar forms in this case, but many of my results extend to arbitrary nonsatiable preferences (see online Appendix A.3). I assume that both u and v are increasing and twice continuously differentiable, with u concave and v convex.

[10] He may, of course, just decide to roll over his position from the previous period. This corresponds to the costless trade that sets ${}_{t-1}b_{t+s} = {}_tb_{t+s}$ and ${}_tB_{t+s} = {}_{t-1}B_{t+s}$ for all s.

Using either a terminal condition if the economy has finite horizon, or a transversality condition if the economy has infinite horizon, the flow budget constraints consolidate into an intertemporal budget constraint:

$$\sum_{t\geq 0} q_t c_t = \underbrace{\sum_{t\geq 0} q_t(y_t + w_t n_t)}_{\omega^H} + \underbrace{\sum_{t\geq 0} q_t\left(\left({}_{-1}b_t\right) + \left(\frac{{}_{-1}B_t}{P_t}\right)\right)}_{\omega^F} \equiv \omega. \tag{2}$$

Equation (2) states that the present value of consumption must be equal to wealth ω: the sum of human wealth ω^H (the present value of all future income) and financial wealth ω^F. Since $\{{}_{-1}B_t\}$ and $\{{}_{-1}b_t\}$ only enter (2) through ω^F, it follows that financial assets with the same initial present value deliver the same solution to the consumer problem. For instance, this framework predicts that a household with an adjustable-rate mortgage (ARM), with ${}_{-1}B_0 = -L$, chooses the same plan for consumption and labor supply as an otherwise identical household with a fixed-rate mortgage (FRM), ${}_{-1}B_t = -M$ for $t = 0, \ldots, T$, provided the two mortgages have the same outstanding principal, i.e., $L = \sum_{t=0}^{T} Q_t M$. In this sense, the composition of balance sheets is irrelevant. But this composition matters following a shock, as the next section shows.

B. *Adjustment after a Transitory Shock*

I now consider an exercise where, keeping balance sheets fixed at $\{{}_{-1}B_t\}_{t\geq 0}$ and $\{{}_{-1}b_t\}_{t\geq 0}$, the paths of variables relevant to the consumer choice problem change in the following way:

(i) All nominal prices rise in proportion, $\frac{dP_t}{P_t} = \frac{dP}{P}$, for $t \geq 0$.

(ii) All present-value real discount rates rise in proportion, $\frac{dq_t}{q_t} = -\frac{dR}{R}$, for $t \geq 1$.

(iii) The Fisher equation holds at the new sequence of prices: $\frac{dQ_t}{Q_t} = -\frac{dR}{R}$, for $t \geq 1$.

(iv) The agent's unearned income at $t = 0$ rises by dy, and his real wage by dw.

This particular variation, depicted in Figure 1, captures in a stylized way the major changes in a consumer's environment that usually follow a temporary change in monetary policy: over a period labeled $t = 0$, incomes and wages increase, the price level rises due to inflation between $t = -1$ and $t = 0$, and the real interest rate $R_0 = q_0/q_1$ falls.[11] As I show formally in online Appendix A.1, these are the changes that occur in the standard representative-agent New Keynesian model following a one-period change in monetary policy. Hence, this variation is a natural starting point for an analysis of the effects of monetary policy on individual households.

[11] The assumption that balance sheets are fixed implies that coupon payments are not contingent on the macroeconomic changes dw, dy, dP, or dR. This is an incomplete markets assumption. If assets payoffs are state-contingent, my results go through provided insurance payments are counted as part of dy.

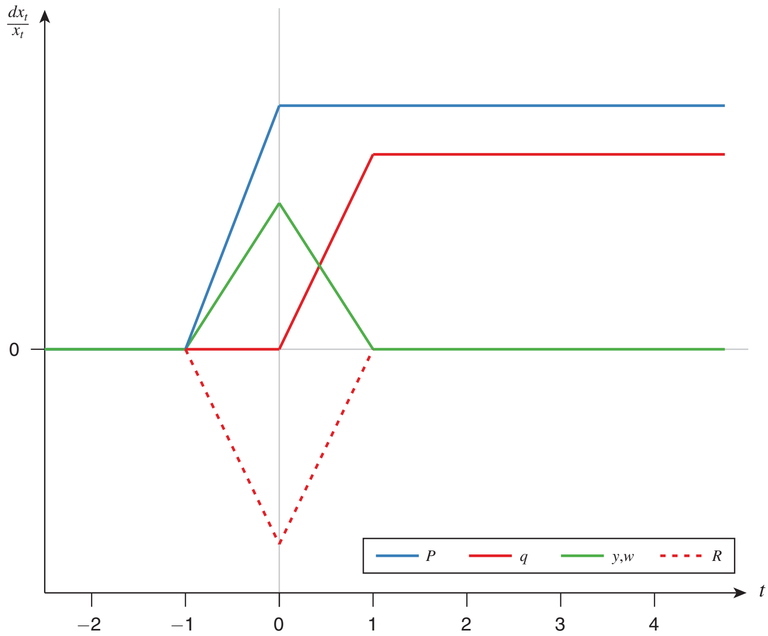

FIGURE 1. THE EXPERIMENT

I am interested in the first-order change in initial consumption $dc \equiv dc_0$, labor supply $dn \equiv dn_0$, and welfare dU that results from this change in the environment.

Let σ and ψ be the local Frisch elasticities of substitution in consumption and hours.[12] Define the marginal propensity to consume as $MPC = \partial c_0/\partial y_0$ along the initial path. When a consumer exogenously receives an extra dollar of income, he increases consumption by MPC dollars, but, to the extent that labor supply is elastic ($\psi > 0$), he also reduces hours by $MPN = \partial n_0/\partial y_0 < 0$, leaving only $MPS = 1 - MPC + w_0 MPN$ dollars for saving.[13]

These behavioral responses to income changes turn out to also matter for the response to the real interest rate, wage, and price level changes, as the following theorem shows.

THEOREM 1: *To first order*, *dropping* $t = 0$ *subscripts whenever unambiguous*,

$$dc = MPC\left(d\Omega + \psi n dw\right) - \sigma c MPS \frac{dR}{R}, \tag{3}$$

$$dn = MPN\left(d\Omega + \psi n dw\right) + \psi n MPS \frac{dR}{R} + \psi n \frac{dw}{w}, \tag{4}$$

$$dU = u'(c) d\Omega, \tag{5}$$

[12] Formally, $\sigma \equiv -\frac{u'(c_0)}{c_0 u''(c_0)} > 0$ and $\psi \equiv \frac{v'(n_0)}{n_0 v''(n_0)} \geq 0$.

[13] Separable utility guarantees that $MPC \in (0,1)$, $MPS \in (0,1)$, and $MPN \leq 0$: in other words, consumption, saving, and leisure are "normal." Below I provide an alternative definition of the marginal propensity to consume that corresponds to the more familiar split between consumption and savings alone.

where $d\Omega$, *the net-of-consumption wealth change*, *is given by*

$$(6) \quad d\Omega = dy + ndw - \sum_{t\geq 0} Q_t\left(\frac{_{-1}B_t}{P_0}\right)\frac{dP}{P} + \left(y + wn + \left(\frac{_{-1}B_0}{P_0}\right) + \left(_{-1}b_0\right) - c\right)\frac{dR}{R}.$$

The theorem, proved in online Appendix A.2, follows from an application of Slutsky's equations, separating the wealth and the substitution effects that result from the shock. The relative price changes dR and dw generate substitution effects on consumption and labor supply with familiar signs, and magnitudes given by a combination of Frisch elasticities and marginal propensities. All wealth effects are aggregated into a net revaluation term, $d\Omega$, which affects consumption and labor supply after multiplication by the marginal propensity to consume and work, respectively.

Note that Theorem 1 makes no assumption on horizon or the form of u and v. In online Appendix A.3, I show that it extends to general utility functions and to persistent shocks.

Unpacking the Net Wealth Revaluation.—The net wealth change $d\Omega$ in (6) is the key expression determining the sign and the magnitude of the welfare and the wealth effects in Theorem 1. This term is a sum of products of *balance-sheet exposures* by *changes in aggregates*. I now describe the terms entering $d\Omega$ one by one.

The first term, $dy + ndw$, is the traditional effect from the change in the present value of income. This is the sum of the unearned income gain, dy, and the change in earned income holding hours fixed, ndw. When the aggregate wage increases by dw, a worker gains more when he initially works more hours n: we say that n represents his exposure to the wage change. (The substitution effect on labor supply from the change in dw is not first-order relevant for welfare, so it does not enter $d\Omega$.)

The second term in $d\Omega$ represents the effect from the immediate and permanent increase in the level of nominal prices, which matters here because of the nominal denomination of assets and liabilities. Define the household's *net nominal position* (NNP) as the present value of his nominal assets, i.e.,

$$NNP \equiv \sum_{t\geq 0} Q_t\left(\frac{_{-1}B_t}{P_0}\right).$$

We can then rewrite the second term in $d\Omega$ as $-NNP(dP/P)$, the product of exposure $-NNP$ by inflation dP/P. Suppose, for example, that nominal prices unexpectedly rise by $dP/P = 1\%$. A nominal saver with $NNP = \$100k$ experiences a wealth effect of $-NNP(dP/P)$, so loses the equivalent of \$1,000.[14] Conversely, a nominal borrower with $NNP = -\$100k$ gains the equivalent of \$1,000. These net nominal positions can be computed directly from a survey of household finances. Doepke and Schneider (2006) conduct this exercise for various groups of US households and show that NNPs are large and heterogeneous in the population: they are

[14] If prices adjust more sluggishly, the Fisher exposure measure changes. For example, if prices adjust only after T (so that $dP_t/P_t = dP/P$ for $t \geq T$), the formulas hold if NNP is replaced by $\sum_{t\geq T} Q_t\left(_{-1}B_t/P_0\right)$, the present value of assets maturing after T. In this case, short-maturity nominal assets maintain constant value, while long-maturity assets decline in value due to the increase in nominal discount rates that follows the expected rise in inflation. The general expression for any given path of price adjustment is given by formula (A.37) in online Appendix A.3.

very positive for rich, old households and negative for the young middle class with mortgage debt. Theorem 1 shows that these numbers are not only relevant for welfare, but also for the consumption response to this inflation scenario. Clearly, the composition of balance sheets matters. Exposures to changes in the level of nominal prices can be avoided by investing all wealth in inflation-indexed instruments, that is, by letting ${}_{-1}B_t = 0$ for all t.

The final term in $d\Omega$ is the wealth effect from the change in the real interest rate. If we define the household*'s unhedged interest rate exposure* (URE) as

$$URE \equiv y + wn + \left(\frac{{}_{-1}B_0}{P_0}\right) + \left({}_{-1}b_0\right) - c,$$

then this final term is equal to $URE(dR/R)$. Observe that URE is the difference between *all* maturing assets (including income) and liabilities (including planned consumption) at time 0. It represents the net saving requirement of the household at time 0, from the point of view of date -1. Because it includes the stocks of financial assets that mature at date 0 rather than interest flows, it can significantly diverge from traditional measures of savings, in particular if investment plans have short durations.

Why is URE the correct measure of exposure following a temporary real interest rate change dR at time 0? To fix ideas, suppose $dR < 0$. This is a decline in the discount rate, which results in an increase in the present value of assets (the traditional capital gains effect). But the present value of liabilities also increases, and consumption is one such liability. Overall, consumers experience a net wealth gain only if their future assets exceed their future liabilities which, in turn, can only happen if their currently-maturing liabilities exceed their currently-maturing assets, i.e., if $URE < 0$. Indeed, equation (2) implies that the difference between future assets and liabilities is

$$\sum_{t\geq 1} q_t(y_t + w_t n_t) + \sum_{t\geq 1} q_t\left(\left({}_{-1}b_t\right) + \left(\frac{{}_{-1}B_t}{P_t}\right)\right) - \sum_{t\geq 1} q_t c_t = -URE.$$

The intuition here is that a rise in the price of future consumption relative to current consumption (an increase in q_t for $t \geq 1$) is the same as a decline in the price of current consumption relative to future consumption (a decline in q_0 holding future q_t fixed). But a fall in the price of current goods benefits those consumers that are demanding more goods than they supply at that date, and conversely, it hurts the net sellers of current goods; URE is the measure of the net exposure to this price change. As I will argue in Section III, URE is *also* measurable from a survey of household finances that has information on income and consumption.[15]

This observation has the important implication that the *duration of asset plans* matters to determine what happens after a change in real interest rates. Fixed rate mortgage holders and annuitized retirees usually have income and outlays roughly balanced, and hence a URE of about zero. By contrast, ARM holders tend to have negative URE, and savers with large amounts of wealth invested at short durations tend to have positive URE. Hence, the theory predicts that the former tend to gain and

[15] By contrast, measuring the exposure to real interest rate changes at any future date requires the knowledge of future income and consumption plans.

the latter tend to lose from a temporary decline in real interest rates.[16] In response, consumption increases whenever the substitution effect dominates the wealth effect. Equation (3) allows us to quantify these two effects, and shows that this happens whenever $\sigma c MPS \geq MPC \cdot URE$.

Monetary Policy and Household Welfare.—Theorem 1 shows that asset value changes give incomplete information to understand the effects of monetary policy on household welfare. In the model just presented, monetary policy can be thought of as influencing asset values through three channels: a risk-free real discount rate effect (dR), an inflation effect (dP), and an effect on dividends (dy). But these asset value changes do not enter $d\Omega$ directly, so they are not relevant on their own to understand who gains and who loses from monetary policy, contrary to what popular discussions sometimes imply. For example, it is sometimes argued that accommodative monetary policy benefits bondholders by increasing bond prices. Yet Theorem 1 shows that, while increases in dividends do raise welfare, lower real risk-free rates have ambiguous effects on savers. They have no effect on bondholders whose dividend streams initially match the difference between their target consumption and other sources of income. They benefit households who hold long-term bonds to finance short-term consumption, through the capital gains they generate. And they hurt households who finance a long consumption stream with short-term bonds, by lowering the rates at which they reinvest their wealth. Unhedged interest rate exposures, not asset price changes, constitute the welfare-relevant metric for the impact of real interest rate changes on households. This is why it is important to measure them.

The Response of Consumption to Overall Income Changes.—Theorem 1 draws a distinction between exogenous changes in income and changes in wages, since the latter have substitution effects on consumption. However, since preferences are separable, it is possible to rewrite the consumption response as a function of the total income change, inclusive of the labor supply response, as I show in online Appendix A.4.

COROLLARY 1: *Given an overall change in income $dY = dy + ndw + wdn$, the household's consumption response is given by*

$$dc = \widehat{MPC}\left(dY - NNP\frac{dP}{P} + URE\frac{dR}{R}\right) - \sigma c\left(1 - \widehat{MPC}\right)\frac{dR}{R}, \tag{7}$$

where

$$\widehat{MPC} = \frac{MPC}{MPC + MPS} = \frac{MPC}{1 + wMPN} \geq MPC.$$

[16] One way to understand the importance of duration is as follows. Consider an agent with financial wealth $\omega^F = \$100k$ that is currently consuming his income $c = y$. Suppose first that this agent has invested all his wealth ω^F in one-period bonds, so that $URE = \omega^F$. Then a temporary one-year decline of 1 percent in the real interest rate requires him to reinvest his wealth at this lower rate, causing a net wealth loss of $URE(dR/R) = -1{,}000\$$. Suppose instead that his wealth is entirely invested in coupon bonds maturing after the first year, so that $URE = 0$. In this case, the high interest rate on assets is "locked in." The net wealth effect is zero because the present value of assets and liabilities both increase by the same amount.

Hence, once we have factored in the endogenous response of income to transfers, the relevant marginal propensity to consume becomes $\widehat{MPC}$, the number between 0 and 1 that determines how the remaining amount of income is split between consumption and savings. This corresponds more closely to the textbook measure of the marginal propensity to consume. It is also what empirical measures tend to pick up, since these are usually regressions of observed consumption on observed income.[17]

Durable Goods.—So far I have restricted my analysis to nondurable consumption. However, durable expenditures tend to account for a substantial share of the overall consumption response to monetary policy shocks, so they are important to consider. Understanding how durable goods fit into the theory also helps deliver an accurate map to consumption data. As I show formally in online Appendix A.5, adding durable goods to the model does not alter the substantive conclusions from Theorem 1, but there are some subtleties.

The most straightforward case is the one in which the relative price of durable goods and nondurable goods is constant. In this case, formulas (3) or (7) continue to hold, provided that c is interpreted as overall expenditures, MPC is the marginal propensity to spend on all goods, URE counts all durable expenditures as part of c, and σ is adjusted upward to reflect the fact that durable goods allow more opportunities for intertemporal substitution.

In multi-sector New Keynesian models with durable goods, a constant relative price of durable goods obtains when the prices of durables and nondurables are equally sticky (Barsky, House, and Kimball 2007). However, there is some evidence that durables have more flexible prices (e.g., Klenow and Malin 2010), in which case these models imply a negative comovement between the relative price of durables p and the nondurable real interest rate R. Let $\epsilon = -\frac{\partial p}{p}\frac{R}{\partial R}$ be the corresponding elasticity. When $\epsilon \neq 0$, nondurables and durables matter separately, so there no longer exists a straightforward notion of aggregate demand. Instead, in online Appendix A.5 I derive separate expressions for the change in nondurable and durable consumption as a function of ϵ. These resemble equations (3) or (7), except for the fact that the expression for c in URE only includes a share $1-\epsilon$ of durable expenditures.[18]

For the purpose of measuring the size of the interest rate exposure channel, I do not have to take a stand on the value of ϵ. In the empirical section, I will assume $\epsilon = 0$ as a benchmark from computing UREs,[19] but I will also show that my empirical results are robust to considering alternative values for ϵ.

Even though all the results presented in this section assume no uncertainty and perfect foresight, they apply directly to environments with uncertainty provided that markets are complete, *except* for the shock that is unexpected (all summations are

[17] When hours affect the marginal utility of consumption, it is generally not possible to obtain an expression such as (7). Instead, dw enters separately, with a sign reflecting the degree of complementarity between consumption and labor supply.

[18] When $\epsilon = 1$, durable purchases are not counted at all in URE, for the same reason that purchases of bonds or shares are not: in this case, durables completely hedge real interest rate movements.

[19] This is a natural benchmark since an ϵ close to 0 is consistent with positive comovement of durables and nondurables after monetary policy shock (see Barsky, House, and Kimball 2007), and would arise endogenously, for example, if wages or intermediate goods prices are sticky, or if there are frictions to the reallocation of labor between sectors in the short run.

then over states as well as dates). An important feature of all these environments is that the marginal propensity to consume, *MPC*, is the same out of all forms of wealth ($\partial c_0/\partial y_0 = \partial c_0/\partial \omega$). The next section relaxes this assumption.

C. *The Consumption Response to Shocks under Incomplete Markets*

I now consider a dynamic, incomplete-market partial equilibrium consumer choice model. Relative to the previous environment, I introduce idiosyncratic income uncertainty, restrict the set of assets that can be traded, and consider borrowing constraints. Specifically, the consumer now faces an idiosyncratic process for real wages $\{w_t\}$ and unearned income $\{y_t\}$. He chooses consumption c_t and labor supply n_t to maximize the separable expected utility function

$$\mathbb{E}\Big[\sum_t \beta^t\{u(c_t) - v(n_t)\}\Big]. \tag{8}$$

The horizon is still not specified in the summation: as in the previous section, it will only influence behavior through its impact on the *MPC*. To model market incompleteness in a general form, I assume that the consumer can trade in N stocks as well as in a nominal long-term bond. In period t, stocks pay real dividends $\mathbf{d}_t = (d_{1t} \; \ldots \; d_{Nt})$ and can be purchased at real prices $\mathbf{S}_t = (S_{1t} \; \ldots \; S_{Nt})$; the consumer's portfolio of shares is denoted by θ_t. Following the standard formulation in the literature, I assume that the long-term bond can be bought at time t at price Q_t and is a promise to pay a geometrically declining nominal coupon with pattern $(1, \delta, \delta^2, \ldots)$ starting at date $t+1$. The current nominal coupon, which I denote Λ_t, then summarizes the entire bond portfolio, so it is not necessary to separately keep track of future coupons. The household's budget constraint at date t is now

$$P_t c_t + Q_t(\Lambda_{t+1} - \delta\Lambda_t) + \theta_{t+1}\cdot P_t\mathbf{S}_t = P_t y_t + P_t w_t n_t + \Lambda_t + \theta_t\cdot(P_t\mathbf{S}_t + P_t\mathbf{d}_t). \tag{9}$$

A borrowing constraint limits trading. This constraint specifies that real end-of-period wealth cannot be too negative. Specifically,

$$\frac{Q_t\Lambda_{t+1} + \theta_{t+1}\cdot P_t\mathbf{S}_t}{P_t} \geq -\frac{\bar{D}}{R_t} \tag{10}$$

for some $\bar{D} \geq 0$, where R_t is the real interest rate at time t. The constraint in (10) is a standard specification for borrowing limits[20] and we will see that it generates reactions of constrained agents to balance sheet revaluations that are closely related to those of unconstrained agents. Given that the extent to which borrowing constraints react to macroeconomic changes is an open question, (10) provides an important benchmark.

Provided that the portfolio choice problem just described has a unique solution at date $t-1$, the household's net nominal position and his unhedged interest rate exposure are both uniquely pinned down in each state at time t. This contrasts with

[20] For example, with short-term debt and no stocks ($N = \delta = 0$), $Q_t = \frac{1}{R_t}\frac{P_t}{P_{t+1}}$ and (10) reads $\frac{\Lambda_{t+1}}{P_{t+1}} \geq -\bar{D}$, as in Eggertsson and Krugman (2012).

the environment in Section IB, where the consumer was indifferent between all portfolio choices. Here, these quantities are defined as

$$
\begin{aligned}
NNP_t &\equiv \left(1 + Q_t \delta\right) \frac{\Lambda_t}{P_t}, \\
URE_t &\equiv y_t + w_t n_t + \frac{\Lambda_t}{P_t} + \theta_t \cdot \mathbf{d}_t - c_t.
\end{aligned}
$$

As before, NNP_t is the real market value of nominal wealth: the sum of the current coupon, Λ_t, and the value of the bond portfolio if it were sold immediately, $Q_t \delta \Lambda_t$. Similarly, URE_t is maturing assets (including income, real coupon payments, and dividends) net of maturing liabilities (including consumption).

Consider the predicted effects on consumption resulting from a simultaneous unexpected change in his current unearned income dy, his current real wage dw, the general price level dP, and the real interest rate dR, for one period only. Assume that this variation leads asset prices to adjust to reflect the change in discounting alone: $dQ/Q = dS_j/S_j = -dR/R$ for $j = 1, \ldots, N$.[21] If $MPC = \partial c/\partial y$, and both MPN and MPS are similarly defined as the responses to current *income* transfers, then the positive results from Theorem 1 carry through.

THEOREM 2: *Assume that the consumer is at an interior optimum, at a binding borrowing constraint, or unable to access financial markets* (*in the latter two cases, let* $MPS = 0$). *Then his first-order change in consumption dc and labor supply dn continue to be given by equations* (3) *and* (4). *In particular, writing* $\widehat{MPC} \equiv \frac{MPC}{MPC + MPS}$, *the relationship between dc and the total change in income* $dY = dy + ndw + wdn$ *is still given by equation* (7).

The proof is given in online Appendix A.6. The intuition for why *MPC*, *MPN*, and *MPS* are relevant to understand the response of all agents to changes in the real interest rate and the price level is simple: when the consumer is locally optimizing, these quantities summarize the way in which he reacts to *all* balance-sheet revaluations, income being only one such revaluation. When the borrowing limit *is* binding, consumption and labor supply adjustments depend on the way the borrowing limit changes when the shock hits. Under the specification in (10), the changes in dR and dP free up borrowing capacity[22] exactly in the amount $-NNP(dP/P) + URE(dR/R)$. Finally, when the consumer is unable to access financial markets, he lives hand-to-mouth so $NNP = URE = 0$. In these latter two cases, $\widehat{MPC} = 1$ and we can interpret the consumption response as a pure wealth effect.

[21] This is a natural assumption that obtains if asset prices are determined in a general equilibrium with incomplete markets. Absence of arbitrage in such a model implies the existence of a probability measure $\mathcal{Q}$ such that the price of each stock j at date 0 is $S_{0j} = \frac{1}{R_0}\mathbb{E}^{\mathcal{Q}}\left[\sum_{t\geq 1}\frac{1}{R_1 \cdots R_{t-1}} d_{jt}\right]$, where R_t is the sequence of risk-free rates. My variation affects R_0 but does not affect future interest rates, dividends, or risk-neutral probabilities, so results in $dS_{0j}/S_{0j} = -dR/R$. The argument for $dQ_0/Q_0 = -dR/R$ is identical.

[22] The form of the borrowing constraint in (10), which imposes a bound on the real value of wealth in period $t+1$, is clearly important for this result. For example, if (10) is replaced by a constraint on the flow of income received from financial markets, $\frac{Q_t \Lambda_{t+1} + \theta_{t+1} \cdot P_t \mathbf{S}_t}{P_t} - \frac{\delta Q_t \Lambda_t + \theta_t \cdot P_t \mathbf{S}_t}{P_t} \geq -\bar{D}$, then the result collapses to $dc = dY$.

By showing that the marginal propensity to consume out of transitory income shocks, which has been the focus of a large empirical literature, remains a key sufficient statistic for predicting behavior with respect to other changes in consumer balance sheets, Theorem 2 provides important theoretical restrictions. The rest of the paper takes these restrictions as given and uses them to predict aggregate consumption responses to changes in R or P. But these restrictions are also directly testable empirically: given independent variation in dP, dy, and dR as well as individual balance sheet information, one could check that individual consumption responds in accordance with equations (3) or (7). This provides an interesting avenue for future empirical work on consumption behavior.

II. Aggregation and the Redistribution Channel

This section shows how the microeconomic demand responses derived in Section I aggregate in general equilibrium to explain the economy-wide response to shocks in a large class of heterogeneous-agent models (Theorem 3).

A. *Environment*

Consider a closed economy populated by I heterogeneous types of agents with separable preferences (8). Each agent type i has its own discount factor β_i, period utility functions u_i and v_i, and time horizon. To accommodate idiosyncratic uncertainty, assume that within each type i there is a mass 1 of individuals, each in an idiosyncratic state $s_{it} \in S_i$. I write $\mathbb{E}_I[z_{it}]$ for the cross-sectional average of any variable z_{it}, taken over individual types I and idiosyncratic states S_i. I write all aggregate variables in per capita units, so for example aggregate (per capita) consumption C_t is equal to average individual consumption $\mathbb{E}_I[c_{it}]$.

Agents and Asset Structure.—Each agent type i in state s_{it} has a stochastic endowment of $e_i(s_{it})$ efficient units of work, and receives a wage of $w_{it} = e_i(s_{it})\,w_t$ per hour, where w_t is the real wage per efficient hour. By choosing n_{it} hours of work, he therefore receives $w_t e_{it} n_{it}$ in earned income. The agent also receives unearned income $y_{it} = d_{it} - t_{it}$, the total dividends on the trees he owns d_{it} net of taxes from the government t_{it}. Let the agent's overall gross-of-tax income be

$$Y_{it} \equiv w_t e_{it} n_{it} + d_{it}. \tag{11}$$

The economy has a fixed supply of aggregate capital K. A set of N trees constitute claims to firm profits and the capital stock. Each tree delivers dividends which, in the aggregate, add up to the sum of aggregate capital income and profits: $\mathbb{E}_I[d_{it}] = \rho_t K + \pi_t$. Agents can also trade nominal government bonds in net supply B_t, as well as a set of $J-1$ additional assets in zero net supply that can be nominal or real. Each agent of type i can trade a subset N_i of the trees and a subset J_i of the other assets. If both N_i and J_i are empty, agents of type i live hand-to-mouth. In other cases, I assume that trading is subject to a type-specific borrowing constraint $\bar{D}_i$, which takes the form in (10) and may be infinite.

Firms.—There exists a competitive firm producing the unique final good in this economy, in quantity Y_t and nominal price P_t, by aggregating intermediate goods with a constant-returns technology. These intermediate goods are produced by a unit mass of firms j under constant returns to scale, using the production functions $X_{jt} = A_{jt} F(K_{jt}, L_{jt})$. Markets for inputs are perfectly competitive, so firms take the real wage w_t and the real rental rate of capital ρ_t as given. These firms sell their products under monopolistic competition and their prices can be sticky. Firm j therefore sets its price P_{jt} at a markup over marginal cost, and it makes real profits π_{jt}.[23] Summing across firms $j \in J$, aggregate production is equal to aggregate income:

$$Y_t = \mathbb{E}_J\left[\frac{P_{jt}}{P_t} X_{jt}\right] = w_t \mathbb{E}_J[L_{jt}] + \rho_t \mathbb{E}_J[K_{jt}] + \mathbb{E}_J[\pi_{jt}]. \tag{12}$$

Government.—A government has nominal short-term debt B_t, spends G_t, and runs the tax-and-transfer system. Its nominal budget constraint is therefore

$$Q_t B_{t+1} = P_t G_t + B_t - P_t \mathbb{E}_I[t_{it}], \tag{13}$$

where $Q_t = \frac{1}{R_t} \frac{P_t}{P_{t+1}}$ is the one-period nominal discount rate. The consequences of price-induced redistributive effects between households and the government depend crucially on the fiscal rule. I assume a simple rule in which the government targets a constant real level of debt $B_t / P_t = \bar{b} > 0$ and spending $G_t = \bar{G} > 0$. I also assume that the government balances its budget at the margin by adjusting all transfers in a lump-sum manner. Hence, unexpected increases in P_t (which create ex post deviations of B_t / P_t from $\bar{b}$) and reductions in the real interest rate R_t result in immediate lump-sum rebates.

Market Clearing.—In equilibrium, the markets for capital, labor, and goods all clear. This implies that at all times t,

$$\mathbb{E}_J[K_{jt}] \equiv K, \tag{14}$$

$$\mathbb{E}_I[e_{it} n_{it}] = \mathbb{E}_J[L_{jt}], \tag{15}$$

$$\mathbb{E}_I[Y_{it}] = Y_t = C_t + G_t. \tag{16}$$

Equilibrium also implies market clearing in all $J + N$ asset markets. This environment nests a large class of one-good, closed economy general equilibrium models. It can accommodate many assumptions about population structure, asset market structure, and participation, heterogeneity in preferences, endowments, and skills, as well as the nature of price stickiness. With some minor modifications, it would accommodate wage stickiness as well. Note that the assumptions made here imply that all agents in this economy essentially solve either the problem in Section IA or that in Section IC.

[23] Specifically, if μ_{jt} is firm j's markup at time t, then $\pi_{jt} = (\mu_{jt} - 1)(w_t L_{jt} + \rho_t K_{jt})$.

B. *Aggregation Result*

I am interested in the aggregate consumption response to a perturbation of this environment in which individual gross incomes dY_i, nominal prices dP, and the real interest rate dR change at $t = 0$ only. This exercise is useful to understand the effect of an *unexpected shock* that has *no persistence.* Let $dY \equiv \mathbb{E}_I[dY_i]$ be the aggregate change in gross income. Assuming labor market clearing after the shock, this is also the aggregate output change.

Aggregation is simplified by several restrictions from market clearing at $t = 0$. Market clearing for nominal assets implies that all nominal positions net out except for that of the government,

$$\mathbb{E}_I[NNP_{it}] = \bar{b} = -NNP_{gt}, \quad \forall t, \tag{17}$$

and market clearing for all assets, combined with (11)–(16) implies[24] that

$$\mathbb{E}_I[URE_{it}] = Y_t - \mathbb{E}_I[t_{it}] + \frac{B_t}{P_t} - C_t = G_t + \frac{B_t}{P_t} - \mathbb{E}_I[t_{it}] = -URE_{gt}, \tag{18}$$

where NNP_{gt} and URE_{gt} are naturally defined as the net nominal position and the unhedged interest rate exposure of the government sector. Equations (17) and (18) are crucial restrictions from general equilibrium: since one agent's asset is another's liability, net nominal positions and interest rate exposures must net out in a closed economy. Aggregation of consumer responses as described by Theorem 2 shows that the per capita aggregate consumption change can be decomposed as the sum of five channels.

THEOREM 3: *To first order, in response to dY_i, dY, dP, and dR, aggregate consumption changes by*

$$\begin{aligned} dC = {} & \underbrace{\mathbb{E}_I\left[\frac{Y_i}{Y}\widehat{MPC}_i\right]dY}_{\text{Aggregate income channel}} + \underbrace{\operatorname{cov}_I\left(\widehat{MPC}_i, dY_i - Y_i\frac{dY}{Y}\right)}_{\text{Earnings heterogeneity channel}} \\ & - \underbrace{\operatorname{cov}_I\left(\widehat{MPC}_i, NNP_i\right)\frac{dP}{P}}_{\text{Fisher channel}} \\ & + \left(\underbrace{\operatorname{cov}_I\left(\widehat{MPC}_i, URE_i\right)}_{\text{Interest rate exposure channel}} - \underbrace{\mathbb{E}_I\left[\sigma_i\left(1-\widehat{MPC}_i\right)c_i\right]}_{\text{Substitution channel}}\right)\frac{dR}{R}. \end{aligned} \tag{19}$$

The proof is given in online Appendix A.7. The key step is to aggregate predictions from Theorem 2, decomposing i's individual income change as $dY_i = (Y_i/Y)\,dY + dY_i - (Y_i/Y)\,dY$ (the sum of an aggregate component and a

[24] To see this, note that if b_{it} denotes the asset coupons that mature at time t for household i, we have $URE_{it} = Y_{it} - t_{it} + b_{it} - c_{it}$. Using market clearing in the $J-1$ zero net supply assets, all these coupons net out except for the government coupon, which here is $\mathbb{E}_I[b_{it}] = B_t/P_t$. The result then follows from goods market clearing and the government budget constraint.

redistributive component), and using market clearing conditions, the fiscal rule, and the fact that $\mathbb{E}_I\left[dY_i - (Y_i/Y)\,dY\right] = 0$ to transform expectations of products into covariances.

Theorem 3 shows that, in the class of environments I consider, a small set of sufficient statistics is enough to understand and predict the first-order response of aggregate consumption to a macroeconomic shock. Equation (19) holds irrespective of the underlying model generating MPCs and exposures at the micro level, as well as the relationship between dY, dP, and dR at the macro level. Most of the bracketed terms are cross-sectional moments that are measurable in household-level microdata and are informative about the economy's macroeconomic response to a shock, no matter the source of this shock. The two exceptions are the EISs σ_i, which need to be obtained from other sources, and $dY_i - Y_i(dY/Y)$, which in general depends on the driving force behind the change in output.

I now use this theorem to discuss the channels of monetary policy transmission under heterogeneity. Alternative applications, for example to short-term redistributive fiscal policy or open-economy models, are also possible.

C. *Monetary Policy Shocks with and without a Representative Agent*

Consider a transitory, accommodative monetary policy shock that, as in Figure 1, lowers the real interest rate and raises aggregate income for one period ($dR < 0$, $dY > 0$), and permanently raises the price level ($dP/P > 0$). Since these are the changes implied by the textbook New Keynesian model with sticky prices and flexible wages after a transitory monetary policy shock, we can apply Theorem 3 to understand the consumption response in that model.

The textbook model features a representative agent ($I = 1$) with separable preferences and EIS σ. Hence, all covariance terms in (19) are zero, and we are left with

$$dC = \widehat{MPC}\,dY - \sigma\left(1 - \widehat{MPC}\right)C\frac{dR}{R}. \tag{20}$$

The first term in (20) is a general-equilibrium income effect, and the second term is a substitution effect.[25] Solving out for $dC = dY$ gives the textbook response, $dC/C = -\sigma(dR/R)$. Intuitively, a Keynesian multiplier $\frac{1}{1-\widehat{MPC}}$ amplifies the initial "first-round" effect from intertemporal substitution. Here this multiplier is entirely microfounded, and in particular takes into account the substitution and wealth effects on labor supply that play out in the background.

Heterogeneity implies a role for redistributive channels in the monetary transmission mechanism, except under special conditions. For example, if aggregate income is distributed proportionally to individual income, so that $dY_i = (Y_i/Y)\,dY$; if no equilibrium asset trade is possible, so that agents consume all their incomes $Y_i = c_i$ and $NNP_i = URE_i = 0$; and if all agents have the same elasticity of intertemporal substitution $\sigma_i = \sigma$, then the representative-agent response $dC/C = -\sigma(dR/R)$

[25] Since the typical calibration of the representative-agent model implies a low $\widehat{MPC}$, the substitution component is typically dominant in this decomposition, as noticed by Kaplan, Moll, and Violante (2018).

obtains even under heterogeneity. Werning (2015) studies this important neutrality result, as well as several extensions.

Away from this benchmark, the redistributive channels of monetary policy can be signed and quantified by measuring the covariance terms in equation (19), either directly in microdata or within a given model. In the next section, I follow the first route to obtain a sense of the plausible empirical magnitudes. As I will show, the data suggest that the following is true:

$$\text{cov}_I\left(\widehat{MPC}_i, URE_i\right) < 0, \tag{21}$$

$$\text{cov}_I\left(\widehat{MPC}_i, NNP_i\right) < 0, \tag{22}$$

$$\text{cov}_I\left(\widehat{MPC}_i, Y_i\right) < 0. \tag{23}$$

These inequalities imply that redistribution *amplifies* the transmission mechanism of monetary policy.

Inequality (21) says that agents with unhedged borrowing requirements have higher marginal propensities to consume than agents with unhedged savings needs. Models with uninsured idiosyncratic risk tend to generate this as an endogenous outcome. Because of this interest rate exposure channel, aggregate consumption is more responsive to real interest rates than measures of intertemporal substitution alone would suggest. In other words, the first-round effect of monetary policy is larger that what the representative-agent model predicts.

Inequality (22) says that net nominal borrowers have higher marginal propensities to consume than net nominal asset holders. This is also an endogenous outcome of typical incomplete market models with nominal assets. It implies that, through its general equilibrium effect on inflation, monetary policy can increase aggregate consumption via a Fisher channel.[26]

Inequality (23) says low-income agents have high MPCs, echoing a finding in much of the empirical literature. On its own, this fact is not enough to sign the earnings heterogeneity channel: we need to know how increases in aggregate income affect agents at different levels of income. More specifically, let

$$\gamma_i \equiv \frac{\partial\left(\frac{Y_i}{Y} - 1\right)}{\left(\frac{Y_i}{Y} - 1\right)} \frac{Y}{\partial Y}, \tag{24}$$

be the elasticity of agent i's relative income to aggregate income. Assume that this is well approximated by a constant γ. Then the earnings heterogeneity channel term in equation (19) simplifies to $\gamma \text{cov}_I(\widehat{MPC}_i, Y_i/Y)\, dY$. There is empirical evidence that income risk is countercyclical (for example, Storesletten, Telmer, and Yaron 2004 or Guvenen, Ozkan, and Song 2014) and that monetary policy accommodations reduce income inequality (Coibion et al. 2017). These studies suggest that γ is negative.

[26] Note that this effect from redistribution is conceptually distinct from the effect of future inflation lowering real interest rates, which has nothing to do with nominal redenomination and is present in representative-agent models with persistent shocks to inflation.

Combining this fact with (23), it is likely that monetary expansions increase aggregate consumption because of their endogenous effect on the income distribution.[27]

Independently of the sign of the covariance terms in (19), Theorem 3 provides an organizing framework for future research on the role of heterogeneity in the transmission mechanism of monetary policy.[28]

D. *Discussion*

I now provide a discussion of my result, highlighting its limitations and possible generalizations.

Interactions between the Household and Other Sectors.—The market clearing equations (17) and (18) respectively state that the net nominal positions and the unhedged interest rate exposure of the combined household and government sectors are zero. This is a theoretical restriction that must hold in a closed economy, provided firms are correctly consolidated as part of the household sector. In practice there are two challenges: actual economies are open, and it is difficult to accurately take into account the indirect exposures through firms when measuring *NNP*s and *URE*s.

In an open economy, (17) and (18) are no longer true, so price-level and real interest rate changes redistribute between the domestic economy and the rest of the world. For example, Doepke and Schneider (2006) find that the net nominal position of the United States is negative, implying that unexpected inflation redistributes toward the US Given a positive average *MPC*, consumption should rise by more than what equation (19) predicts. Similarly, Gourinchas and Rey (2007) find that the United States borrows short and lends long on its international portfolio, suggesting that it has a negative unhedged interest rate exposure. Hence, US households benefit *on average* from lower real interest rates. This could contribute to the expansionary effects of monetary accommodations on consumption.[29]

The assumption that households and firms are consolidated is also important. For example, the household sector tends to be maturity mismatched, holding relatively short-term assets (deposits) and relatively long-term liabilities (fixed-rate mortgages). To a large extent, this is a counterpart to the reverse situation in the banking sector. An ideal measure of *URE*s and *NNP*s would take into account the indirect exposures that each household has through the firms it has a stake in. In practice, this is very challenging to do.

[27] Away from separable preferences, an additional *complementarity channel* of monetary policy can arise, even with a representative agent, when preferences are such that increases in hours worked increase the marginal utility of consumption.

[28] An early generation of papers in the heterogeneous agent New Keynesian literature analyzed the transmission of monetary policy under limited heterogeneity. In "saver-spender" models, such as Bilbiie (2008), "spender" agents live hand-to-mouth and consume their incomes, so they have $\widehat{MPC} = 1$; while "saver" agents have access to financial markets, with a low $\widehat{MPC}$. This has the effect of increasing the aggregate MPC in the economy, raising the importance of income effects relative to substitution effects in equation (19). In "borrower-saver" models, as in Iacoviello (2005), the high-MPC agents are also borrowers. The literature usually assumes short-term debt, implying (21) and sometimes also nominal debt, implying (22). However, whether (23) holds crucially depends on the assumptions these papers make about the distribution of wages and profits across savers versus spenders.

[29] To the extent that these gains are evenly distributed across the population, these effects can be quantified, respectively, by evaluating $\mathbb{E}_I[\widehat{MPC}_i] \cdot NNP_{US}$ and $\mathbb{E}_I[\widehat{MPC}_i] \cdot URE_{US}$.

When we undercount household exposures to negative-URE sectors, we obtain a positive $\mathbb{E}_I[URE_i]$. This is situation also arises in the model of Section II, but there the negative-URE outside sector is the government. The logic of Theorem 3 shows that, if marginal rebates from other sectors were immediate and lump-sum, this mismeasurement would be irrelevant. In practice, rebates are likely to be delayed, and they could disproportionately affect higher or lower MPC agents, so that the numbers could depart from my benchmark covariance expression in either direction.

One way to assess the importance of all these effects is to directly measure in the data expressions such as $\mathbb{E}_I\left[\widehat{MPC}_i URE_i\right]$ and to compare them to the covariance numbers. These "no-rebate" numbers replace the covariance terms in (19) under the assumption that none of the outside sectors rebate gains to the household sector. In this context, it is theoretically possible for the interest rate exposure term $\mathbb{E}_I\left[\widehat{MPC}_i URE_i\right]$ to be both positive and larger than the substitution term in (19). This suggests that, in a world in which outside rebates are highly delayed or benefit low-MPC agents, real interest rate cuts could *lower* aggregate consumption demand, significantly altering the conventional understanding of how monetary policy operates.[30]

General Equilibrium and Persistent Shocks.—Theorem 3 provides the response of consumption to a *transitory* shock to R, P, and Y. While this exercise provides an insightful decomposition that has the merit of involving measurable sufficient statistics, it has two major limitations.

First, the exercise is partial equilibrium in nature: in general, Theorem 3 does not permit us to solve for the general equilibrium consumption effect of a given exogenous shock. This is because even transitory exogenous shocks tend to have long-lasting effects on agent behavior and the wealth distribution, which in general equilibrium tends to generate adjustments in future interest rates and/or income. Equation (19) does characterize the full equilibrium in my leading case of the benchmark New Keynesian model, but in more general heterogeneous-agent models it will typically only hold as an approximation of the consumption response to a transitory monetary policy shock.[31]

Second, empirically, monetary policy changes tend to be persistent. Persistent shocks make the derivation of sufficient statistics much more difficult: for example, to characterize the effect of future changes in R, one needs to know the distribution of future consumption and income plans.

In the context of a given structural model, it is possible to extend my decomposition in (19) to any degree of persistence, as shown by Kaplan, Moll, and Violante (2018). As models grow in complexity and realism, the importance of the channels identified in Theorem 3 can be assessed and refined using such a procedure. I believe that my key finding that redistribution amplifies the effects of monetary policy is likely to remain robust, but it will certainly need to be qualified. In particular, the

[30] This theoretical possibility is sometimes mentioned in economic discussions of monetary policy. See Raghuram Rajan ("Interestingly [...] low rates could even hurt overall spending"), *Money Magic*, Project Syndicate, November 11, 2013.

[31] For instance, the theorem cannot accommodate capital investment, where a current fall in the real interest rate $dR < 0$ comes together with a future fall in capital income, $d\rho_1 < 0$. A previous version of this paper (Auclert 2017) showed the quality of the approximation $dC \simeq dY$ in the context of a model without investment.

work of Christiano, Eichenbaum, and Evans (2005) and many others suggests that the empirical consumption response to identified monetary policy shocks builds up over time. Whether redistribution channel mechanisms can explain this persistence, and not just the impact response, remains an open question.

E. *Estimable Moments*

Some of the terms in equation (19) require knowledge of additional information before they can be taken to the data. I make two further assumptions on these structural parameters so as to turn the equation into a full set of estimable moments. For convenience, I also rewrite the decomposition in terms of elasticities.

COROLLARY 2: *Assume that individuals have common elasticity of intertemporal substitution, $\sigma_i = \sigma$, and common elasticity of relative income to aggregate income, $\gamma_i = \gamma$ for all i. Then,*

$$\frac{dC}{C} = \left(\mathcal{M} + \gamma\mathcal{E}_Y\right)\frac{dY}{Y} - \mathcal{E}_P\frac{dP}{P} + \left(\mathcal{E}_R - \sigma S\right)\frac{dR}{R}, \tag{25}$$

where $\mathcal{M}$, $\mathcal{E}_Y$, $\mathcal{E}_P$, $\mathcal{E}_R$, and S are measurable cross-sectional moments summarized in Table 1.

The proof is in online Appendix A.8. The assumption of a constant γ parametrizes the incidence of increases in aggregate output dY using a convenient functional form.[32] As is clear from equation (24), when $\gamma > 0$, agents with income above the mean benefit disproportionately from such an increase. The opposite happens when $\gamma < 0$. As discussed above, the evidence on the cyclicality of income risk tends to suggest that the latter case is plausible, though a constant γ is clearly a strong assumption.

Table 1 summarizes the definitions of the moments entering equation (25). I call $\mathcal{E}_P$, $\mathcal{E}_R$, and $\mathcal{E}_Y$ the *redistribution elasticities* of consumption with respect to the price level, the real interest rate and income, since these terms enter explicitly as elasticities in equation (25).[33] The next section measures these numbers in the data.

III. Measuring the Redistribution Elasticities of Consumption

This section turns to data from three surveys to get a sense of the empirical magnitudes of each of the terms in Table 1. This exercise is not intended as definitive and will need to be refined in future work. Yet we will see that it paints a fairly consistent picture, one in which inequalities (21)–(23) are satisfied. With these moment estimates in hand, only two parameters in equation (25) remain unknown. Note

[32] Such a specification appears, for example, if labor supply is inelastic ($\psi = 0$) and all income is labor income ($d = 0$). In this case, agent i's gross earnings are $e_i Y$, the product of his skills e_i and aggregate output Y. Suppose that the government taxes these earnings at a rate $\tau(Y)$ and rebates them lump-sum. Then post-redistribution earnings are $Y_i = \left(\left(1 - \tau(Y)\right)e_i + \tau(Y)\mathbb{E}[e_i]\right)Y$. A constant γ_i follows if the net-of-tax rate has constant elasticity with respect to output, i.e., $\frac{\tau'(Y)}{1-\tau(Y)} = -\gamma$.

[33] Calling $\mathcal{E}_Y$ an elasticity is a slight abuse of terminology, since the actual elasticity is $\gamma\mathcal{E}_Y$.

TABLE 1—SEVEN CROSS-SECTIONAL MOMENTS THAT DETERMINE CONSUMPTION IN (25)

	Definition	Name	Channel
$\mathcal{E}_R$	$\mathrm{cov}_I\left(MPC_i, \frac{URE_i}{\mathbb{E}_I[c_i]}\right)$	Redistribution elasticity for R	Interest-rate exposure
$\mathcal{E}_R^{NR}$	$\mathbb{E}_I\left[MPC_i \frac{URE_i}{\mathbb{E}_I[c_i]}\right]$	—, no rebate	—
$\hat{S}$	$\mathbb{E}_I\left[(1-MPC_i)\frac{c_i}{\mathbb{E}_I[c_i]}\right]$	Hicksian scaling factor	Substitution
$\mathcal{E}_P$	$\mathrm{cov}_I\left(MPC_i, \frac{NNP_i}{\mathbb{E}_I[c_i]}\right)$	Redistribution elasticity for P	Fisher
$\mathcal{E}_P^{NR}$	$\mathbb{E}_I\left[MPC_i \frac{NNP_i}{\mathbb{E}_I[c_i]}\right]$	—, no rebate	—
$\mathcal{E}_Y$	$\mathrm{cov}_I\left(MPC_i, \frac{Y_i}{\mathbb{E}_I[c_i]}\right)$	Redistribution elasticity for Y	Earnings heterogeneity
$\mathcal{M}$	$\mathbb{E}_I\left[MPC_i \frac{Y_i}{\mathbb{E}_I[c_i]}\right]$	Income-weighted MPC	Aggregate income

that σ can be obtained from the vast literature studying the elasticity of intertemporal substitution, and γ can be obtained from studies on the cyclicality of income distribution.

A. *Three Surveys, Three Identification Strategies*

In order to compute my key cross-sectional moments, I need household-level information on income, consumption, and balance sheets. This information is available in household surveys from various countries. I also need information on $\widehat{MPC}$, the marginal propensity to consume out of transitory income shocks.[34] The literature has used various techniques to estimate these MPCs (see Jappelli and Pistaferri 2010 for a survey). Three of the most influential approaches are implementable using public survey data. I compute my moments using all three approaches, each in a different survey. These surveys cover two countries and three different time periods. Given that sufficient statistics are likely to vary over time and across countries, this exercise gives a sense of robustness to the fundamental setting as well as the estimation method. Since I build on standard references in the literature, I restrict myself to a brief description of these methods, and refer the reader to online Appendix C and to the original sources for further detail.

My first source of data is the Italian Survey of Household Income and Wealth (SHIW).[35] In 2010, the survey asked households to self-report the part of any hypothetical windfall that they would immediately spend (Jappelli and Pistaferri 2014). The benefit of this approach is that the windfall can be taken as exogenous for all agents, so in principle this empirical measure of MPC is the number that matters for the theory. Another benefit of this survey measure is that it provides MPCs at the household level, making it easy to compute covariances with individual

[34] Recall that the theory makes a distinction between $\widehat{MPC}$, which takes into account the endogenous response of labor supply, and MPC which does not. The methods used to compute MPC either regress observed consumption on observed income, or ask a question to respondents without mentioning a potential labor supply adjustment, so from now on I assume that they measure $\widehat{MPC}$, and I sometimes write it MPC for convenience.

[35] Bank of Italy (2010).

balance-sheet information. On the other hand, a concern with self-reported answers to hypothetical situations is that they may not be informative about how households would actually behave in these situations. The other two measures I consider estimate MPCs from actual behavior instead.

My second source of data is the US Panel Study of Income Dynamics (PSID),[36] where I use a "semi-structural" approach to compute MPCs out of transitory income shocks. The procedure is due to Blundell, Pistaferri, and Preston (2008) and has since been popularized by Kaplan, Violante, and Weidner (2014) and others. The idea is to postulate an income process and a consumption function, and to use restrictions from the theory to back out the MPC out of transitory shocks from the joint cross-sectional distribution of consumption changes and income changes. Since this procedure can only recover an estimate at the group level, I compute my redistribution elasticities by first grouping households into different bins, then estimating MPCs within bins and covariances across bins. One drawback of such a procedure is that it generates large error bands.

My third source of data is the US Consumer Expenditure Survey (CE),[37] in which MPC is identified using exogenous income variation following Johnson, Parker, and Souleles (2006). These authors estimate the MPC out of the 2001 tax rebate by exploiting random variation in the timing of the receipt of this rebate across households. Since the policy was announced ahead of time, they identify the MPC out of an increase in income that is expected in advance. This is, in general, different from the theoretically-consistent MPC out of an unexpected increase. However, to the extent that borrowing constraints are important, or if households are surprised by the receipt despite its announcement, the resulting estimate may be close to the MPC that is important for the theory. This procedure also yields an MPC at a group level, so I again estimate covariances across groups, and this also delivers large error bands.

Each of these three techniques has its own limitations, and no survey contains perfect information on all components of household balance sheets. Notably, consumption in the SHIW and the PSID is imperfectly measured, as are income and assets in the CE. In addition, none of these surveys samples very rich households whose consumption behavior may be an important determinant of aggregate expenditures. Hence, the exercise in this section is tentative and intended to give a sense of magnitudes based on the current state of knowledge in the field. As administrative data on consumption, income, and wealth become available and more sophisticated identification methods for *MPC*s develop, a priority for future work is to refine the estimates I provide here.

B. *Measurement*

Even though my analysis is in terms of elasticities, which are unitless numbers, the choice of temporal units is important: *MPC* needs to be measured over a period of time consistent with the time unit for income, consumption, and maturing elements of the balance sheet. To maximize comparability across surveys, I conduct all my measurement at an annual rate. While this is generally straightforward to

[36] Survey Research Center, Institute for Social Research, University of Michigan (1999–2013).
[37] US Department of Labor, Bureau of Labor Statistics (2000–2002).

do, MPCs require special treatment. Specifically, in the CE, the MPC identification strategy yields a quarterly estimate MPC^Q. I convert these to an annual MPC number MPC^A using the simple formula $MPC^A = 1 - \left(1 - MPC^Q\right)^4$. In online Appendix B, I provide a formal justification for this procedure.[38]

MPC.—I choose a benchmark of $\epsilon = 0$ for the elasticity of the relative price of durables to the real interest rate. Accordingly, my ideal measure of MPC includes total expenditures on nondurable and durable goods. The question in the SHIW refers to "spending" without distinguishing between types of purchases, so it is safe to assume that it refers to both durables and nondurables. For my US exercises, I prefer to follow the baseline estimates from Blundell, Pistaferri, and Preston (2008) and Johnson, Parker, and Souleles (2006), neither of which include durable goods in MPC estimation. Hence, my PSID estimate only includes nondurables, while my main CE estimate only includes food. In online Appendix C.4.1 I consider robustness to using total expenditures to estimate MPC instead. This makes the point estimates more negative, but also increases the confidence intervals. In online Appendix C.4.2, I consider robustness to alternative values of ϵ, which has a similar effect.

URE.—As defined in Section IB, URE_i measures the total resource flow that a household i needs to invest over the first period of his consumption plan. In each survey, I construct URE_i as

$$URE_i = Y_i - T_i - C_i + A_i - L_i, \tag{26}$$

where Y_i is gross income, T_i is taxes net of transfers, C_i is consumption, and A_i and L_i represent, respectively, assets and liabilities that mature over the period, over and above the amounts already included in Y_i or C_i. I now describe what I include in these terms in detail. Table 2 provides a summary of the discussion that follows.

The term Y_i includes gross income from all sources: labor, dividend, and interest income, as well as realized capital gains. This counts the maturing portion of equities, provided that we assume that equities have infinite maturity.[39] Note that Y_i also counts bond coupons, with the remainder of maturing bonds included in A_i instead. The term T_i counts all taxes net of all transfers, so $Y_i - T_i$ represents disposable income.

Given my benchmark of $\epsilon = 0$, I include in C_i all expenditures including rents and interest payments, as well as expenditure on durable goods including housing purchases and maintenance. In robustness exercises with respect to ϵ, I only include in C_i a fraction $1 - \epsilon$ of durable expenditures. In addition, I include all amortization payments in C_i. This accounts for the maturing portions of installment debt as well as fixed rate mortgages.

These choices leave me to account for four remaining categories of maturing assets and liabilities: deposits, bonds, adjustable rate mortgages,[40] and credit cards.

[38] In online Appendix C.4.4 I measure *MPC* and *URE* at a quarterly rate instead. This delivers similar results.

[39] I do not include unrealized capital gains in Y_i, consistent with an interpretation of these unrealized capital gains as resulting from real interest rates movements to which UREs summarize the exposure.

[40] In the United States, fixed-rate mortgages carry a low-cost refinancing option. One possibility is to treat them as adjustable rate mortgages for rate cuts. Each household then has a different *URE* for rate increases versus

Table 2—Mapping Model to Data Objects

Exposure measure: URE	Data	Quarterly	Short	Benchmark	Long	Annual
		Duration assumptions by scenario (years)				
Y_i	Gross income (all sources)					
T_i	Taxes net of transfers					
C_i	Nondurables $+ (1-\epsilon) \times$ durables					
A_i	Deposits	0.25	0.25	0.5	0.75	1
	Bonds	4 (US), 7 (Italian government), 3.5 (Italian corporate)				
L_i	Adjustable rate mortgages	0.25	0.5	0.75	1	1
	Credit cards	0.25	0.25	0.5	0.75	1

Exposure measure: NNP	Data
Nominal assets	Deposits + bonds
Nominal liabilities	Mortgages + consumer debt

Since I only observe very coarse maturity information in the data, I need to make assumptions on durations to convert stocks to flows. I define a benchmark scenario based on the limited external information I have, as well as four other scenarios to reflect uncertainty regarding true durations in the data. Table 2 summarizes these assumptions.

For remaining maturing assets A_i, I assume in my benchmark that time and savings deposits have a duration of two quarters. I assume that all bonds have a duration of four years in the United States, matching the average duration of assets calculated by Doepke and Schneider (2006). For Italy, where I have separate information on holdings of government and corporate bonds, I use the average duration of 2010 government debt documented by the Italian Department of the Treasury (seven years), and assume that the maturity of corporate bonds is half as long.

For remaining maturing liabilities L_i, I assume a duration of three quarters for ARMs based on the results of Stanton and Wallace (1999). For credit cards, I assume a duration of two quarters. Table 2 shows my assumptions for shorter and longer duration scenarios.

NNP and Income.—I compute net nominal positions as the difference between directly held nominal assets (deposits and bonds) and directly held nominal liabilities (mortgages and consumer credit). When assets are clearly indicated as shares of a financial intermediary that mostly owns nominal assets (for example, money market mutual funds), I also include the value of these shares in the households' nominal position. However, relative to Doepke and Schneider (2006), I do not calculate the indirect nominal positions arising from holdings of equity or other financial intermediaries, since my data are not sufficiently detailed for this purpose. For my income exposure measure, in keeping with the theory, I use pre-tax income (Y_i) in all three surveys.

Measurement Error.—Measurement error is a very important issue in this exercise. These errors can stem from many sources: poor data quality, imperfect coverage, underreporting of consumption, or timing differences in the reporting of

rate cuts. Estimated in this way, the aggregate redistribution elasticity $\widehat{\mathcal{E}}_R$ for rate cuts is similar in the PSID, and it almost doubles in the CE.

TABLE 3—MAIN SUMMARY STATISTICS FROM THE THREE SURVEYS

Survey:	SHIW		PSID		CE	
	Mean	SD	Mean	SD	Mean	SD
Net income $(Y_i - T_i)$	1.19	0.83	1.42	1.64	1.14	1.01
Consumption (C_i)	1.00	0.94	1.00	2.58	1.00	0.90
Maturing assets (A_i)	0.93	2.48	1.30	5.06	0.53	1.77
Maturing liabilities (L_i)	0.31	1.40	0.51	1.44	0.52	1.47
Unhedged interest rate exposure (URE_i)	0.81	3.04	1.21	6.06	0.18	2.43
Nominal assets	0.74	2.36	1.18	3.66	0.47	1.84
Nominal liabilities	0.50	1.49	1.73	2.75	1.22	1.90
Net nominal position (NNP_i)	0.24	2.64	−0.55	4.43	−0.68	2.47
Gross income (Y_i)	1.27	1.04	1.69	2.51	1.23	1.09
Marginal propensity to consume (MPC_i)	0.47	0.35				
Number of households	7,951		7,287		4,833	

Notes: In each survey, *Mean* and *SD* represent the sample mean and standard deviation. All statistics are computed using sample weights. All variables except for *MPC* are normalized by average consumption in the sample.

consumption and income. Each survey has its own strengths and weaknesses. The CE has excellent information on consumption and liabilities, but limited information on assets. Both the PSID and the SHIW appear to significantly undermeasure consumption. My covariance estimates are unbiased provided that the measurement errors in *MPC* and its cross-term $(URE, NNP$, or $Y)$ are additive and uncorrelated. Economically, this assumption corresponds to the presence of a "mismeasurement" sector that rebates gains and losses lump-sum, just as the government does in the setting of Theorem 3.[41] This is certainly a strong assumption. The difference between my benchmark elasticities and their no-rebate counterpart can give a sense of the magnitude of this mismeasurement problem.

Summary Statistics.—Table 3 reports the main summary statistics from each survey. Each line is normalized by average consumption in the survey, which facilitates comparability and corresponds to the normalization behind my elasticities in Table 1. Note that the average *URE* is positive all three surveys. One reason, in addition to those highlighted in Section IIE, is that consumption is below income at the mean, especially in the PSID and the SHIW, likely because of underreporting and coverage issues. The average net nominal position is quite negative in CE and PSID, possibly reflecting a poor measure of assets, and moderately positive in the Italian survey, where few households have a mortgage.

C. *Redistribution Elasticities in the Data*

I now turn to my main empirical results. Figure 2 reports the distribution of MPC by URE, NNP, and income across the three surveys. Columns correspond to datasets, and rows to exposure measures. The first column displays data from the SHIW, where

[41] For example, by abstracting away from indirect exposures to the banking sector, I tend to overstate the aggregate *URE*. If gains to the banking sector disproportionately favor low-*MPC* households, my estimate of the MPC/URE correlation would be biased downward.

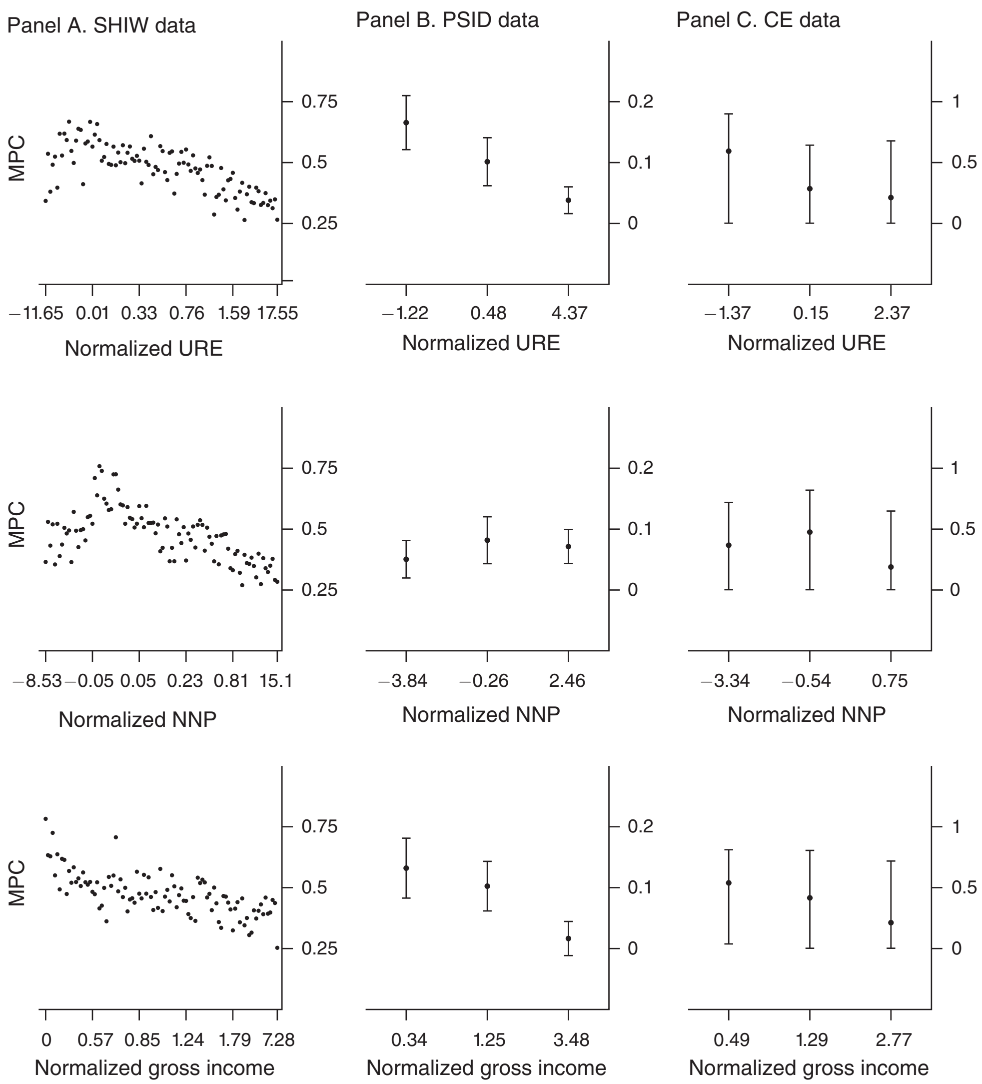

Figure 2. Marginal Propensities to Consume and the Redistribution Channels

Notes: This graphs shows average annual marginal propensities to consume by exposure bin. The top row groups households by unhedged interest rate exposure (URE), the middle row by net nominal position (NNP), and the third row by gross (pre-tax) income. The x-axes report mean exposure per bin (all exposure measures are normalized by average consumption). Panel A uses 100 bins in the SHIW. Panels B and C use 3 bins in the PSID and the CE, respectively, and estimate MPC within bin. See the main text for details on MPC estimation.

individual MPC information is available. The three graphs report the average value of MPC in each percentile of the x-axis variable. In the PSID (second column) and the CE (third column), I estimate the MPC by stratifying the population in terciles of the x-axis variable, and then report the point estimate together with confidence intervals within each bin.

Starting with the interest exposure channel, looking across the first row, all three surveys show a negative correlation between MPC and URE. This is particularly apparent in the SHIW and the PSID data, but the pattern is there in the CE as well. A direct implication is that $\mathcal{E}_R < 0$ in each of these datasets: falls in interest rates increase consumption demand via the redistribution channel.

Turning to the Fisher channel, we also observe an overall negative correlation in the SHIW, though it is somewhat less pronounced. This weaker pattern is apparent in the PSID and the CE as well: in particular, MPCs tend to be slightly higher in the center of the NNP distribution than at the extremes. This could be consistent with a "wealthy hand-to-mouth" explanation as in Kaplan and Violante (2014). Overall, the slight diminishing pattern suggests that $\mathcal{E}_P < 0$, consistent with Fisher's hypothesis: unexpected increases in nominal prices tend to increase consumption overall, but this effect tends to be quantitatively small.

Finally, across all three surveys, the covariance between MPCs and gross incomes is also negative, confirming previous findings in the literature. Combined with $\gamma < 0$, a negative $\mathcal{E}_Y$ implies an amplification role for the earnings heterogeneity channel in the transmission of monetary policy.

Moving on to magnitudes, Table 4 computes my seven key cross-sectional moments, together with 95 percent confidence intervals. For the PSID and the CE, the estimation is done across bins by using three bins, just as in Figure 2.[42]

Confirming the visual impression from Figure 2, the point estimates for the redistribution elasticities $\widehat{\mathcal{E}}_R$, $\widehat{\mathcal{E}}_P$, and $\widehat{\mathcal{E}}_Y$ are negative in all three surveys, except for a slight positive number for $\widehat{\mathcal{E}}_P$ in the PSID. However, the magnitudes are relatively small; in particular, the confidence bands in the CE always include zero.[43]

To put these numbers in the context of standard representative-agent analyses, consider that many macroeconomists believe 0.1 to 0.5 as plausible values for the elasticity of intertemporal substitution σ, though financial economists typically consider σ to be above 1. (In his meta-analysis, Havránek 2015 finds a mean of $\sigma = 0.5$ but argues that it is pushed up by publication bias, while Bansal, Kiku, and Yaron 2016's preferred estimate is $\sigma = 2.2$.) Equation (25) shows that σ should be compared to $-\mathcal{E}_R/S$ to gauge the relative strength of the redistribution effect. According to the point estimates from Table 4, this number is between 0.1 and 0.4. Hence, the data suggest that, if σ is as small as macroeconomists think, the redistribution effect may be as important as the substitution effect in explaining why aggregate consumption responds to changes in real interest rates. On the other hand, the magnitudes of $\widehat{\mathcal{E}}_P$ and $\widehat{\mathcal{E}}_Y$ are fairly small, so that (unless γ is very negative) neither channel can account on its own for very large movements in consumption. But their combined effect may nevertheless be substantial, and further research is needed to refine the precision of these estimates.

As more sources of joint consumption, income and asset data become available, a better empirical understanding of *URE*s and *NNP*s will become possible, helping to shape our understanding of the winners and losers from changes in real interest rates and inflation. Real-time estimates of the redistribution covariances could also provide useful information about the dynamic evolution of the monetary policy transmission mechanism.

[42] Online Appendix C.4.3 reports a sensitivity analysis using four to eight bins. The results are little changed.

[43] Moreover, the estimated value of $\mathcal{E}_R^{NR}$ is usually positive, implying that the negative covariance is not strong enough to overwhelm the positive value of URE at the mean.

Table 4—Estimates of Table 1's Cross-Sectional Moments in Three Surveys

Survey:	SHIW		PSID		CE	
	Estimate	95 percent CI	Estimate	95 percent CI	Estimate	95 percent CI
$\widehat{\mathcal{E}}_R$	−0.10	[−0.15,−0.05]	−0.12	[−0.16, −0.08]	−0.23	[−0.60, 0.15]
$\widehat{\mathcal{E}}_R^{NR}$	0.28	[0.23,0.33]	0.00	[−0.03, 0.04]	−0.09	[−0.48, 0.31]
$\widehat{S}$	0.55	[0.53,0.58]	0.90	[0.88, 0.92]	0.64	[0.36, 0.92]
$\widehat{\mathcal{E}}_P$	−0.07	[−0.11,−0.02]	0.02	[−0.02, 0.07]	−0.09	[−0.51, 0.33]
$\widehat{\mathcal{E}}_P^{NR}$	0.05	[0.01, 0.09]	−0.01	[−0.06, 0.03]	−0.45	[−0.94, 0.04]
$\widehat{\mathcal{E}_Y}$	−0.05	[−0.07, −0.03]	−0.06	[−0.09,−0.04]	−0.13	[−0.36, 0.10]
$\widehat{\mathcal{M}}$	0.55	[0.53, 0.57]	0.08	[0.04, 0.12]	0.46	[−0.06, 0.98]

Notes: All statistics are computed using survey weights. In the *CE* and the *PSID* columns, confidence intervals are bootstrapped by resampling households 100 times with replacement.

Table 5—Estimated Redistribution Elasticity $\mathcal{E}_R$ for Five Duration Scenarios

		Duration scenario				
		Quarterly	Short	Benchmark	Long	Annual
$\widehat{\mathcal{E}}_R$	SHIW	−0.16 [−0.27, −0.06]	−0.20 [−0.27, −0.12]	−0.10 [−0.15, −0.05]	−0.07 [−0.11, −0.04]	−0.06 [−0.09,−0.02]
	PSID	−0.14 [−0.21, −0.07]	−0.13 [−0.20, −0.07]	−0.12 [−0.16, −0.08]	−0.11 [−0.15, −0.08]	−0.11 [−0.14,−0.08]
	CE	−0.55 [−1.35,0.24]	−0.48 [−1.10, 0.14]	−0.23 [−0.60, 0.15]	−0.22 [−0.50, 0.06]	−0.23 [−0.49,0.03]

The Role of Asset and Liability Durations.—Table 5 considers the sensitivity of my estimates of $\mathcal{E}_R$ to my maturity assumptions listed in Table 2. In all three surveys, shortening durations makes the redistribution elasticity more negative, while lengthening durations makes it approach zero. This finding illustrates the importance of durations in determining the magnitude of the interest rate exposure channel. As I discuss below, this finding has a simple structural interpretation in incomplete market models.

D. *Empirical Drivers of the Redistribution Covariances*

While the sufficient statistic approach suggests that only the population-level redistribution elasticities matter to determine an overall effect, in practice it is interesting to understand the empirical drivers of these covariances. For example, is the covariance between *MPC* and *URE* negative because older households tend to have lower *MPC*s and higher *URE*s? In order to shed light on this and related questions, I perform a covariance decomposition, projecting each covariance onto observable components such as age or education. This procedure is inspired by the law of total covariance: focusing on *URE* for ease of notation, for any covariate Z_i we know that

$$(27)\quad \mathrm{cov}\big(MPC_i, URE_i\big) = \underbrace{\mathrm{cov}\Big(\mathbb{E}\big[MPC_i|Z_i\big], \mathbb{E}\big[URE_i|Z_i\big]\Big)}_{\text{Explained fraction of covariance}} + \underbrace{\mathbb{E}\Big[\mathrm{cov}\big(MPC_i, URE_i|Z_i\big)\Big]}_{\text{Unexplained fraction of covariance}}.$$

We can then implement this decomposition using an ordinary least squarse (OLS) regression, which performs a linear approximation to the conditional expectation function.[44] For any observable covariate Z_i, I run two OLS regressions,

$$MPC_i = \alpha_M + \beta_M Z_i + \epsilon_{Mi},$$

$$URE_i = \alpha_R + \beta_R Z_i + \epsilon_{Ri},$$

and compute the covariance between the fitted values $\widehat{MPC}_i$ and $\widehat{URE}_i$ to get an empirical counterpart of the explained component in (27). This gives me the part of the covariance that can be explained by Z_i, since

$$\begin{aligned}
\text{(28)} \qquad \operatorname{cov}(MPC_i, URE_i) &= \operatorname{cov}\left(\widehat{MPC}_i + \hat{\epsilon}_{Mi}, \widehat{URE}_i + \hat{\epsilon}_{Ri}\right) \\
&= \operatorname{cov}\left(\widehat{\beta}_M Z_i + \hat{\epsilon}_{Mi}, \widehat{\beta}_R Z_i + \hat{\epsilon}_{Ri}\right) \\
&= \operatorname{var}(Z_i)\widehat{\beta}_M\widehat{\beta}_R + \operatorname{cov}\left(\hat{\epsilon}_{Mi}, \hat{\epsilon}_{Ri}\right),
\end{aligned}$$

where the last line follows because, by construction, $\operatorname{cov}(\hat{\epsilon}_{Mi}, Z_i) = \operatorname{cov}(\hat{\epsilon}_{Ri}, Z_i) = 0$. For example, in Table 6, when Z_i is age, $\widehat{\beta}_M$ is negative and $\widehat{\beta}_R$ is positive, so older agents do tend to have lower *MPC* and higher *URE*. However, on its own, age can only explain 9 percent of the total covariance.

This procedure is straightforward to implement in the SHIW, where *MPC* is available at the individual level. Table 6 reports these results using Jappelli and Pistaferri's (2014) control variables for MPC, one covariate at a time. For each of my three redistributive channels, I report each of the terms in the decomposition (28), as well as the fraction of the variance explained. In online Appendix C.5, I generalize this approach to multiple covariates, and I also report estimates of MPC, URE, and NNP by age and income bins in each survey. All of these give a consistent message: age, education, and income tend to be negatively correlated with MPC and positively correlated with URE and NNP, so they help explain the negative covariance overall.

E. *Sufficient Statistics: Model versus Data*

In a previous version of this paper (Auclert 2017), I considered the sufficient statistics generated by a standard partial-equilibrium incomplete markets model, similar to the one used as a building block by the heterogeneous-agent New Keynesian literature. The model is a Bewley-Huggett-Aiyagari model with nominal, long-term, circulating private IOUs (as in Huggett 1993). Such a model features rich heterogeneity in MPCs, UREs, NNPs, and incomes. I calibrated it to the US economy and quantitatively evaluated, in its steady state, the size of my sufficient statistics. This exercise delivered three main insights.

[44] This is similar to implementing the law of total variance using R^2.

Table 6—Covariance Decomposition for URE, NNP, and Income in the SHIW

			$\mathcal{E}_R$		$\mathcal{E}_P$		$\mathcal{E}_Y$	
Z_i	var(Z_i)	$\widehat{\beta}_M$	$\widehat{\beta}_R$	% expl.	$\widehat{\beta}_P$	% expl.	$\widehat{\beta}_Y$	% expl.
Age bins	0.77	−0.027	0.467	10	0.472	15	−0.008	−0
Male	0.24	−0.055	0.352	5	0.258	5	0.271	7
Married	0.18	−0.016	0.069	0	−0.063	−0	0.449	2
Years of education	18.8	−0.005	0.052	5	0.028	4	0.097	19
Family size	1.71	0.023	−0.094	4	−0.194	12	0.149	−11
Resident of the South	0.22	0.198	−0.443	18	−0.231	15	−0.567	48
City size	1.21	0.037	0.013	−0	0.048	−3	0.058	−5
Unemployed	0.04	0.189	−0.610	5	−0.278	3	−0.637	10

First, in the model, the interest rate exposure channel has the same sign and comparable magnitude as it does in the data. Moreover, as durations shorten, the redistribution elasticity becomes more negative, consistent with my findings in Table 5. In the limit where all assets are short term, changes in real interest rates have large redistributive effects. The intuition is as follows: the shorter asset maturities are, the less capital gains expansionary monetary policy generates. Since capital gains accrue to low MPC agents, monetary policy is more potent in affecting consumption with short-term assets than with long-term assets. This role for asset durations is consistent with the results of Calza, Monacelli, and Stracca (2013), who find that consumption reacts much more strongly to identified monetary policy shocks in countries where mortgages predominantly have adjustable rates.[45]

Second, I find that a calibration of the model in which all assets are nominal features a Fisher channel with the same sign as in the data, but a much larger magnitude. This is because inflation redistributes along the asset dimension, which in this class of models is highly correlated with MPC. As a result, Bewley models with nominal assets tend to overstate the correlation between MPCs and NNPs that exists in the data. A model with real assets, or in which assets have a high degree of inflation indexation, is more consistent with the empirical evidence.

Finally, in the model with short-term debt, changes in real interest rates have asymmetric effects. The sufficient statistic approach correctly predicts the effect of any increase in the real rate, but it overpredicts the effect of a large decline. This asymmetry comes from the differential response of borrowers at their credit limit to rises and falls in income: while these borrowers save an important fraction of the gains they get from low interest rates, they are forced to cut spending steeply when interest rates rise. This could help explain the empirical finding that interest rate hikes tend to lower output by more than falls increase it (Cover 1992, de Long and Summers 1988, Tenreyro and Thwaites 2016). My explanation, which has to do with asymmetric MPC differences in response to policy rate changes, provides an alternative to the traditional Keynesian interpretation of this fact, which relies on downward nominal wage rigidities.[46]

[45] See also Rubio (2011) and Garriga, Kydland, and Šustek (2017).

[46] In practice, the refinancing option embedded in fixed rate mortgages in the United States is likely to create an asymmetric effect in the opposite direction from the one I stress here. See Wong (2018) for theory and empirical evidence along these lines.

IV. Conclusion

This paper contributes to our understanding of the role of heterogeneity in the transmission mechanism of monetary policy. I identified three important dimensions along which monetary policy redistributes income and wealth, and argued that each of these dimensions was likely to be a source of aggregate effects on consumption. My classification holds in many environments and provides a simple, reduced-form approach to computing aggregate magnitudes. Hence, it can guide future work on the topic, both theoretical and empirical.

An important finding of my paper is that capital gains and losses, both nominal and real, matter for understanding monetary policy transmission. This finding has broad implications for monetary policy. A change in the inflation target can create large redistribution in favor of high MPC agents and be expansionary over and beyond its effect on real interest rates. With long asset maturities, lower real interest rates can benefit asset holders with lower MPCs and make interest rate cuts less effective at increasing aggregate demand than they would otherwise be. Monetary policy becomes intertwined with fiscal policy, but also with government debt maturity management and mortgage design policies.

These are just some of the macroeconomic consequences of the presence of large and heterogeneous marginal propensities to consume, which are a robust feature of household microdata. My investigation opens up many avenues for future research on monetary policy with heterogeneous agents.

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