Do Mortgage Subsidies Help or Hurt Borrowers?*

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Abstract

The welfare evaluation of debt subsidies, using a sufficient statistics approach, has not accounted for the effect of changes in the price of the assets financed with this debt. In this paper, I extend the classic framework for applied welfare analysis to evaluate the welfare effects of mortgage subsidies, accounting for changes in house prices. I generalize the sufficient statistics formulas to describe the effect of mortgage subsidies on house prices, individual welfare, and efficiency costs, yielding novel insights. First, individual welfare depends on the loan-to-value ratio in addition to the classic statistics describing the elasticity of demand and supply. Second, borrowers might be hurt by linear borrowing subsidies, as they act as non-linear subsidies for total financing costs. Third, the increase in house prices attenuates the efficiency cost of mortgage subsidies. I use my generalized sufficient statistics formulas to gauge the effects of eliminating mortgage deductions. In particular, I calculate the elasticity of house prices to mortgage rates for 269 metropolitan areas and estimate the distributional impact on households' welfare. Moreover, my estimates suggest that efficiency gains from eliminating these deductions are 40 percent lower than without the attenuating effect of house price changes. My results open new avenues for applied welfare analysis of credit policies.

JEL classification: H22, R21, R28.

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1 Introduction

Subsidies that reduce the cost of debt for households or firms are commonly used with the objective to promote the expenditure on the assets financed with this debt. For example, mortgage interest deductions subsidize housing,[1] reduced rates on student loans subsidize higher education, and tax breaks on corporate debt subsidize corporate investment. To evaluate the effect of these policies, it is necessary to consider the effect they will have on the cost of both debt and the debt-financed asset. But, to the best of my knowledge, the welfare evaluation of debt subsidies using a sufficient statistics approach has not accounted for the effect of changes in asset prices. Using this approach, this paper evaluates the welfare effects of mortgage subsidies, accounting for the role of house price changes.

In the first half of the paper, I generalize the textbook model for welfare evaluation of tax policy to show analytically the role of house price changes. I characterize by simple formulas, as functions of reduced-form sufficient statistics that can be empirically identified, the effects of mortgage subsidies on house prices, individual welfare, and efficiency costs. In the second half of the paper, I use my generalized formulas to gauge the magnitude of these effects that would be brought about by the elimination of mortgage interest deductions (MID) across U.S. metropolitan regions. This application illustrates the role of house price changes for the welfare evaluation of mortgage subsidies.

To characterize theoretically the effect of mortgage subsidies, I extend the classic framework for applied welfare analysis to an intertemporal setting, where households purchase durable houses and finance them with mortgage debt.[2] Importantly, I assume that households cannot save at the rate that they can borrow, so financial markets are imperfect and households' financing decisions are uniquely pinned down. In fact, I show that households finance their house using first internal funds and then mortgage debt, so the marginal user cost of homeownership for borrowers depends on the effective mortgage rate. Therefore, the marginal user cost is independent of the opportunity cost of the downpayment and the fraction of housing financed with mortgage debt, i.e., the loan-to-value (LTV) ratio. It follows that mortgage subsidies lower homeownership marginal costs, thus increasing the demand for, and the price of, housing. Using my extended framework, I show that financial market imperfections and house price changes have important consequences for the welfare evaluation of mortgage subsidies.

[1] This was the fourth largest federal tax expenditure in 2015 (Office of Management and Budget 2015). In addition, mortgage rate subsidies are provided through the intermediation of mortgage credit by government-sponsored enterprises, like Fannie Mae and Freddie Mac, which guarantee mortgages sold in the secondary market. It has been estimated that this guarantee reduces effective mortgage rates by about 25 basis points (CBO 2001, Ambrose et al. 2004, Sherlund 2008, and DeFusco and Paciorek 2017).

[2] For a textbook version of this model, see Mas Colell, Whinston, and Green (2005). Kotlikoff and Summers (1987) and Auerbach (1985) survey the incidence and efficiency costs results in this literature, respectively.

First, imperfect financial markets increase information requirements for the evaluation of debt policy. In fact, with imperfect financial markets, the LTV ratio is an additional statistic for the measurement of the welfare effect of mortgage subsidies on individual households. With imperfect financial markets, the LTV ratio is uniquely pinned down, as opposed to the case of perfect financial markets, where this ratio is undetermined. Intuitively, the LTV ratio is needed to account for the fact that the benefit from lower mortgage interest payments accrues only to the fraction of housing expenditure financed with mortgage debt.

Second, accounting for house price responses to mortgage subsidies can overturn the classic result that subsidies always (weakly) benefit their recipients. In fact, linear mortgage subsidies impact households' welfare as non-linear subsidies for the total financing cost of housing, because the subsidy fully distorts the marginal user cost of homeownership but is received only on the fraction financed with mortgage debt—the LTV ratio. Then, first-time buyers can be hurt by mortgage subsidies! This result challenges the intuition from the classic analysis of taxes and subsidies, where subsidies always (weakly) benefit their recipients. As in the classic case, mortgage subsidies benefit buyers by reducing mortgage interest payments and create an offsetting effect by increasing the demand and price of housing. Intuitively, mortgage subsidies affect house prices as if the house was financed entirely with mortgage debt. By contrast, the subsidy is effectively received only on the fraction financed with mortgage debt, equal to the LTV ratio. So when the LTV is sufficiently low, the effective subsidy is low, whereas the house price increase, which hurts first-time buyers, is unaffected. Therefore, when the LTV is small relative to the increase in house prices, first-time buyers are hurt by mortgage subsidies.

I provide an analytical expression for the critical LTV value that determines the sign of the welfare effect on first-time buyers in terms of the demand and supply elasticities that pin down house price changes. House price changes are larger, and the critical LTV is larger, when the supply (demand) of housing is more price inelastic (elastic).[3]

Third, the increase in house prices reduces the efficiency loss of mortgage subsidies. As in the classic case, the subsidy creates a deadweight loss in the mortgage market because it distorts an optimal allocation, so the welfare cost of collecting the required tax revenue to finance the subsidy is larger than the benefit perceived by households from the subsidy. But higher house prices reduce the (compensated) mortgage demand and thus the deadweight loss generated by the subsidy. Thus, the deadweight loss from mortgage subsidies is smaller than what obtains using the sufficient statistics formula that abstracts from the adjustment in house prices. The difference caused by the adjustment in house prices is economically significant, as I show in the second part of the paper.

In the second part of the paper, I use my generalized welfare formulas to provide new esti-

[3] I use the convention that more elastic refers to a larger elasticity in absolute value.

mates of the effect of eliminating MID. I consider a sample of 17.6 million mortgages originated in 2010-2015, in 269 metropolitan areas, together with available estimates for the other key parameters. Assuming that housing markets are geographically segmented, I produce estimates for 269 metropolitan areas of the house price declines and efficiency gains caused by the elimination of MID, and of the distributional impact on individual households' welfare of this policy change.

One challenge for accounting for the effect of asset prices in general, and of house prices in particular, in the sufficient statistics framework is the empirical identification of the interest rate demand elasticity for the asset or the debt used to finance the asset. This identification is challenging because any change of interest rates is expected to influence asset demand and thus the asset price, complicating the identification of only a change in interest rates on the asset demand.[4] Similarly, the demand for debt responds to both the interest rate and the asset price. To overcome this challenge, I establish, under very general assumptions, that the mortgage rate semielasticity of house demand equals the ratio between the price house demand elasticity and the individual user cost of homeownership (Lemma 1). Using this relationship together with existing estimates for the price demand elasticity of housing and the user cost, I estimate an average mortgage rate semielasticity of -15.3 (Section 3).

Using my estimates of the mortgage rate semielasticity of house demand, my sample of mortgages, and available estimates of the other key parameters I estimate the effect of eliminating MID on house prices, individual households' welfare, and efficiency gains.

First, I estimate the effect of eliminating MID on house prices for the 269 metropolitan areas in my sample. Using the sufficient statistics formulas, I estimate a (house-value-weighted) average mortgage-rate semielasticity of house prices of -6.9. That is, a 1 percentage point reduction in the mortgage rate will increase house price by 6.9 percent on average. My estimates for this elasticity vary across regions primarily due to differences in the house price elasticity of supply, which are obtained from Saiz (2010). I estimate an elasticity of house prices with respect to mortgage rates ranging from -9.6 in Miami, Florida, where house supply is the most inelastic, to -1.2 in Pine Bluff, Arizona, where the supply is the most elastic. My estimates are broadly in line with other estimates in the literature that estimate these elasticities directly from the data but my estimates offer a higher level of regional granularity. These estimates imply a (house-value-weighted) average decline of house prices of 6.9 percent from eliminating MID.

Second, I provide estimates of the distributional impact on households' welfare, or the incidence, of eliminating MID, depending on households' mortgage characteristics and the estimated local house price decline. As described by my incidence formulas, the elimination of MID has a

[4] This is especially challenging in the case of housing and mortgage markets, as house prices are negotiated bilaterally. So even if a single household randomly receives a lower mortgage rate, the price she will negotiate for her house is expected to be affected.

different effect on first-time homebuyers and homeowners. Both sets of households are hurt from the elimination of MID, which increases their effective mortgage interest rate. However, homebuyers benefit from the drop in house prices, whereas homeowners are additionally hurt by it. I estimate that on average homeowners welfare drops by 11.5 percent of the value of their house, whereas homebuyers welfare drops only by 8.5 percent of the value of their house. For an average house value of $320,000 these effects correspond to a present value loss of $36,800 for homeowners and a loss of $27,200 for homebuyers. In other words, current MID are more helpful for existing homeowners relative to first-time buyers. Given the differential response of house prices and different characteristics of households' mortgage contracts the average incidence is also estimated to vary across regions. I estimate that on average homebuyers' welfare decline by 12.6 percent of the house value in Alexandria, Louisiana, whereas homebuyers in San Francisco, where house prices are estimates to drop more, are estimated to lose only 3.8 percent of the house value (representing losses of $40,320 and $12,160 for a $320,000 house, respectively).

Finally, I estimate the efficiency gains from the elimination of MID. As the theoretical framework highlights, these gains are attenuated by the effect of mortgage rates on house prices. I estimate that for my sample of 17.6 million households efficiency gains total $2.6 billion, or an average efficiency gain of 5 basis points of the house value. Extrapolating to the 49 million households that finance their homes with mortgage debt (U.S. Census Bureau 2010-2014) total efficiency gains would increase to a modest $7.3 billion. My estimates imply that these losses are 40 percent lower than without the attenuating effect of house prices.

My paper relates to three strands of the literature. First, my paper contributes to the public economics literature that utilizes the sufficient statistics approach to analyse imperfect financial markets, arguing that asset price changes are key for the welfare evaluation of debt policies. The sufficient statistics approach traces its origins to the work by Harberger (1964) and combines the advantage of the cleaner identification of reduced-form parameters with the ability of structural models to describe welfare effects (Chetty 2009). Using this approach Matvos (2013) studies how covenants create benefits for corporate borrowers by completing debt contracts. Dávila (2015) analyzes optimal bankruptcy exceptions for unsecured debt. Auclert (2016) studies the role of redistribution in the transmission of monetary policy, when financial markets are incomplete due to borrowing limits and limited financial assets available for trade. By contrast, I study an environment with real housing assets and where financial market imperfections preclude households to save at the rate they can borrow. Nonetheless, as I do, Auclert obtains that to evaluate welfare balance sheet information is needed and changes in financial asset prices should be accounted for. Although I focus on the case of mortgages and housing, the techniques and insights developed here are suitable to analyze debt policies in other contexts where debt is used to finance real asset expenditures, like corporate investment in fixed assets or college students' investment in human capital.[5] My results open new avenues for applied welfare analysis in these settings.

Second, my paper contributes to the literature that uses the sufficient statistics approach to analyze the effect of housing policy, and mortgage policy in particular (cf., Laidler 1969, Aaron 1972, Rosen 1979, Poterba 1992, Poterba and Sinai 2008). This literature considers how mortgage subsidies and other policies affect the house rental rate and evaluates the welfare effect of these policies using a rich description of the U.S. tax code. For instance, Poterba (1992) and Poterba and Sinai (2008) gauge the efficiency cost and distributional impact of MID, respectively, abstracting from the adjustment in house prices. Relative to this literature I focus on the tax provisions that affect the cost of mortgage debt, I consider imperfect financial markets, I relax the assumption that house prices are fixed, and I consider individual heterogeneity in mortgage contract characteristics. My analysis shows that the response of house prices introduces significant regional variation for the effect of mortgage policy and that ignoring this response will overstate the efficiency cost of these subsidies. In fact, my results suggest that the efficiency costs of MID are about 40 percent smaller than without the attenuating effect of house prices, as estimated in previous studies.

A related literature has looked at the effect of MID on homeownership, or the extensive margin of housing demand. For example, Bourassa and Yin (2008) conclude that MID reduce homeownership rates of young households due to the effect on house prices. In addition, Glaeser and Shapiro (2003), analyzing time and cross-state variation in MID, find that the effect of MID in homeownership is small. Similarly, Hilber and Turner (2014) present evidence based on within- and across-state variation in MID over time showing that this subsidy is ineffective in promoting homeownership. Hilber and Turner (2014) argue that the capitalization into house prices offsets the reduction on homeowners' rental rates brought about by MID. Furthermore, Sommer and Sullivan (2016) study the impact of MID on a quantitative macroeconomic model with endogenous tenure choice, rents, and house prices. Counterfactual analysis in the Sommer-Sullivan model shows that eliminating MID will increase homeownership rates, instead of reducing them.[6] These studies and my analysis share the emphasis on the capitalization into house prices of mortgage subsidies. However, this strand of the literature highlights the trade-off between renting and owning and the importance of the extensive margin of housing demand, which I abstract away from in my analysis. But, the conclusion of these studies lend some support to my focus on the adjustment along the intensive margin of house demand, as most of the response to mortgage subsidies is expected to occur along this margin.

[5]A related literature has considered the effect of debt subsidies for the optimal capital structure of corporations. For recent contributions, see De Mooij (2012) and Weichenrieder and Klautke (2008), and for surveys see Auerbach (2002) and Graham (2008). But this literature abstracts away from the price of capital-good inputs.

[6]Other studies have evaluated, using a structural approach, the welfare effects of changes in effective mortgage rates generated by the role of the Government Sponsored Enterprises in the intermediation of mortgage credit. For reecnt examples, see Jeske, Krueger, and Mitman (2013) and Hurst et al. (2016).

Finally, my paper contributes to the literature that studies the effect of mortgage credit on house prices. Using my sufficient statistics formulas, I estimate an average mortgage rate semielasticity of house prices of -6.9 across the 269 metropolitan areas in my sample, which is broadly in line with direct estimates from empirical studies (Glaeser, Gottlieb, and Gyourko 2012, Adelino, Schoar, and Severino 2014, Kung 2015). The simple sufficient statistics formulas can also be used to estimate the effect of the quantity of credit on house prices: the elasticity of house prices with respect to the volume of mortgage loans. I obtain an average estimate for this elasticity of 0.3 in line with the direct estimates of Favara and Imbs (2015) and Di Maggio and Kermani (2015). My estimates support the conclusion of Glaeser, Gottlieb, and Gyourko (2012) that the decline in interest rates in the early 2000s cannot explain the increase in house prices in this period. Like these authors, I derive a formula for the semielasticity of house prices with respect to mortgage rates, which incorporates endogenous house supply. But instead of focussing on the extensive margin of house demand, I focus on the intensive margin. As in Glaeser, Gottlieb, and Gyourko (2012), when house supply is totally inelastic, I recover a semielasticity of house prices with respect to real mortgage rates close to -20, as in Himmelberg, Mayer, and Sinai (2005) and as prescribed by the static asset market approach to house valuation (Poterba 1984).

The rest of the paper is organized as follows. Section 2 presents the theoretical framework and the analytical characterization of the effects of mortgage subsidies. Section 3 describes the data used to quantify the effect of eliminating MID. Section 4 presents my estimates of the effect of eliminating MID by metropolitan area on house prices, households' welfare, and efficiency gains. Section 5 provides some concluding remarks. And an Appendix contains additional material.

2 Theoretical Framework

In this section I extend the simple model for applied welfare analysis to characterize the effect of mortgage subsidies. Importantly, the cost of mortgage debt affects households' housing demand and financing decisions—the LTV on their house purchases. Moreover, house demand affects the price of housing, which in turn influences housing and mortgage demand. I describe by simple formulas, as functions of reduced-form sufficient statistics, the role of mortgage subsidies in determining house price changes, economic incidence, and efficiency costs.

2.1 Setup

I consider an economy with two periods, $t = 0, 1$. The economy is populated by households (homebuyers and homeowners), house producers, and lenders. There are two goods, durable housing and perishable consumption, which is the numeraire. In addition, household can borrow from lenders using mortgages that may be subsidized by the government.

Homebuyers. There is a continuum of mass 1 of identical homebuyers who derive utility from housing purchased in period 0, x, and period 1 consumption, c. I abstract away from non-housing consumption that could take place in period 0 for simplicity and consider period 1 consumption to capture the intertemporal nature of mortgage borrowing. Buyers' preferences are represented by $u(x,c)$, which is increasing and concave in each argument. This preference specification is very general as it does not impose separability between the utility derived from housing and period 1 consumption.

Homebuyers receive income y in period 0 in units of the numeraire. They have no initial housing units, but can purchase them in period 0 at price p. Homebuyers can finance their house purchases with their income or mortgage debt, denoted by m. Each unit of mortgage borrowing requires the homebuyer to pay a unit of the numeraire in period 1 in exchange for q units of the numeraire in period 0. A mortgage subsidy t adds to the amount received by borrowers in period 0, so after the subsidy borrowers receive $q + t$ units in period 0, per unit promised.[7] Using this notation the loan-to-value (LTV) ratio equals $(q + t)m/px$. Homebuyers also pay lump-sum taxes T in period 0.

In the model, house prices in period 1 are exogenous, as the model abstract away from the equilibrium of the housing market in that period. However, in order to account for the main determinants of the user cost of housing—expected capital gains and depreciation—I assume that the house price in period 1 is proportional to the endogenous house price in period 0. In particular, I assume that this price reflects (expected) house price appreciation π and the depreciation of the housing stock δ, thus the house price in period 1 equals $(1 + \pi - \delta)p$. Under these assumptions the budget constraint in period 0 and 1 are given, respectively, by $px + T \leq y + (q + t)m$ and $c \leq (1 + \pi - \delta)px - m$. Finally, I assume that both consumption and mortgages are non-negative.[8]

In general, homebuyers will choose different combinations of housing, consumption, and mortgage debt depending on the price of housing and mortgages, and households' preferences and income. To illustrate the effect of mortgage subsidies, I focus on buyers at an interior solution where optimality imply that

$$\frac{u_x}{u_c} = [r(t) + \delta - \pi]\, p\ , \tag{1}$$

where u_x (u_c) corresponds to the marginal utility of housing (consumption), and $r(t) = 1/(q+t)-1$ corresponds to the effective mortgage interest rate after the subsidy. The term in square brackets in equation (1) corresponds to the user cost of homeownership, which is increasing in the effective

[7]Using the mortgage price q, instead of the mortgage interest rate, simplifies the analysis of efficiency costs below. But this is equivalent, up-to a first order approximation, to working with a subsidy on the mortgage interest rate: where mortgages provide a unit of the numeraire in period 0 in exchange for a payment of $1 + r = 1/q$ in period 1.

[8]Non-negative consumption imposes a natural borrowing limit, and the non-negativity of mortgages prevent buyers from saving at the mortgage rate, which is without loss of generality as I focus on unconstrained borrowers.

mortgage rate and depreciation, and decreasing in expected capital gains (cf. Poterba 1984, or Himmelberg, Mayer, and Sinai 2005). Note that the mortgage subsidy fully distort the cost of funds in the user cost expression, i.e., the effective marginal user cost is the same regardless of what fraction of the house is financed with mortgage debt—the LTV ratio—and what fraction is financed with a downpayment. This result follows from the pecking order generated by financial market imperfections. Households finance their house expenditure using first internal funds, i.e., their income, and only then using mortgage debt. Then, at the margin borrowers trade-off present and future consumption at the mortgage interest rate. This result has important implications for the effect of mortgage subsidies and holds as long as borrowers cannot invest at interest rates higher than the mortgage rate.[9]

Homeowners and house producers. To highlight the distributional effects through house prices on existing homeowners and house producers, I consider these agents separately. There is a continuum of mass 1 of identical homeowners and a continuum of mass 1 of identical house producers. Homeowners have a fixed endowment of houses h and have linear preferences for the proceeds of house sales, ph. Homeowners derive utility of house sales, so they will always sell all their house endowment.[10] In addition, houses are produced by price taking firms that produce z housing units at a cost $\kappa(z)$, which is increasing and quasi-convex. Firms optimal behavior imply $p = \kappa'(z)$, which implicitly define producers' house supply. Therefore, total house supply $S = h + z$.

Lenders. There is a continuum of mass 1 of identical lenders, who maximize profits. Lenders have deep pockets and an opportunity cost of funds given by r_f. For each loan, lenders give borrowers $q = 1/(1 + r)$ units of consumption in period 0 and are promised 1 unit of consumption in period 1. Lenders operate a constant return to scale technology, which reflects origination and servicing costs ρ per loan. Thus, lenders maximization problem corresponds to $\max_l (r - r_f - \rho)l$. Lenders optimal behavior will pin down the lending mortgage rate $r = r_f + \rho$. That is, mortgage supply is effectively totally elastic at $r_f + \rho$. This is a consequence of the simplifying assumptions on this part of the model: constant funding cost and constant return to scale technology.

Government. The government collects lump-sum taxes T from consumers in period 0 in order to finance mortgage subsidies. Given a government policy, $\{t, T\}$, the government needs to balance its budget in period 0, i.e., $tm = T$. I assume that the government collects non-distortionary taxes in terms of period 0 income to simplify the efficiency analysis in the presence of income effects (see Auerbach 1985).

[9]Note that free-disposal makes the model isomorphic to a model where savings earn a −100% return. The same pecking order is obtained in a model where households can save at an interest rate that is strictly lower than the effective mortgage rate $r(t)$.

[10]In keeping with the simplicity of the model, in this section homeowners are assumed to sell their houses inelastically. Nonetheless, in the analysis of section 4 homeowners will be identified with mortgage refinancing, so they will be affected both by the reduction of effective mortgage rates and the change in house prices.

In this environment a competitive equilibrium is defined as follows.

Definition 1 (Competitive Equilibrium) *A competitive equilibrium consists of a house price, p, a mortgage rate, r, allocations for homebuyers, $\{x,\ c,\ m\}$, loan supply, l, house production, z, homeowners' sales, h, and government policy, $\{t, T\}$, such that: homebuyers, homeowners, house producers, and lenders behave optimally taking prices as given, the housing and mortgage markets clear, and the government runs a balanced budget.*

In an effort to maintain the simplicity of the model I have abstracted away from several features that are relevant in practice. These features are not required to describe the results but influence the welfare estimates presented in section 4. First, the model abstract from uncertainty about income and house prices. The former will introduce a precautionary motive reducing the demand for mortgage debt. The latter increases the user cost of home ownership. In fact, following Poterba (1992) and others, for the measurement exercise of section 4, I consider that the user cost comprises a term that captures a risk premium for housing investment.[11]

Second, the model abstract from other forms of borrowing and savings. This simplification is not instrumental for the results in this setting without uncertainty, as long as saving instruments offer an interest rate lower than the mortgage rate, and other forms of borrowing have higher interest rates than mortgages. These conditions seem plausible: risk-adjusted saving rates are lower than borrowing rates, as reflected by positive bank interest rate spreads in practice and as required by no-arbitrage conditions in theory; and mortgage (and other securitized borrowing) rates are lower than rates on unsecured forms of credit, as collateral enhances lenders' recovery rates.

Third, I abstract away from homebuyers' income in period 1. Future income affects the demand for housing, as it affects homebuyers' lifetime income, but it does not change the optimality condition for an interior equilibrium (equation (1)). Therefore, the analysis will remain unchanged when future income is considered, unless the homebuyer is constrained in the amount she can borrow using mortgage debt. This will be the case when there are minimum downpayment requirements, or equivalently, maximum LTV limits, a case that is discussed below.

Finally, I abstract away from the extensive margin for housing demand. Incorporating a rental market in the analysis is expected to influence the welfare evaluation of mortgage subsidies. These subsidies may induce renters to become homeowners directly impacting households' welfare. But, as my analysis and related literature emphasize, the capitalization into house prices of mortgage subsidies increases the rental rate of homeownership, which the subsidy aimed to decrease. The overall effect of mortgage subsidies on the incentive to own versus to rent is thus ambiguous. The available research on the effect of MID on homeownership rates suggests that the overall effect of these subsidies on homeownership rates is small (Glaeser and Shapiro 2003, Bourassa and

[11]When I calibrate the user cost to the data I will take into account the presence of this and additional terms of the user cost of home ownership that I have abstracted away in the simple model.

Yin 2008, Hilber and Turner 2014, Sommer and Sullivan 2016). The conclusion of these studies suggests that most of the response to MID is expected to occur along the intensive margin of house demand, which I consider in my framework.

2.2 The Incidence of Mortgage Subsidies

How are the costs and benefits of a mortgage subsidy shared between homebuyers, homeowners, house producers, and lenders in equilibrium, when these subsidies affect house prices? To answer this question, in this section I derive formulas for the incidence of mortgage subsidies that parallel the derivations of Kotlikoff and Summers (1987).

Let D be the aggregate demand for houses, which from equation (1) depends on the house price, p, and the after-subsidy mortgage rate, $r(t)$. In addition, the uncompensated individual and aggregate demand functions will depend on households' income, y. In addition, let S be the total supply of houses, which is only a function of house prices, as homeowners will always sell their house endowment and house producers will adjust their production plans depending on the level of house prices. Then, house market clearing requires that

$$D(p, r(t), y) = S(p) \ . \tag{2}$$

To describe the behavior of house prices and the incidence of mortgage subsidies it is useful to introduce the following notation. Let $\varepsilon_{D,p} = (\partial D/\partial p)\ p/D$ and $\varepsilon_{S,p} = (dS/dp)\ p/S$ denote the price elasticity of housing demand and supply, respectively, let $\zeta_{D,r} = (\partial D/\partial r)/D$ denote the mortgage-rate semielasticity of house demand, and let $\zeta_{p,r} = (\partial p/\partial r)/p$ denote the mortgage-rate semielasticity of house prices. In addition, for a given mortgage subsidy, t, let $p(t)$ denote the house price that obtains in equilibrium. The following result follows.

Proposition 1 (Incidence of Mortgage Subsidies) *The incidence of increasing the mortgage subsidy, t, equals zero for lenders, $-(1 + r(t))^2 zp\zeta_{p,r}$ for house producers, $-(1 + r(t))^2 hp\zeta_{p,r}$ for homeowners, and*

$$u_c px(1 + r(t))^2 \left(\zeta_{p,r}[r(t) + \delta - \pi] + LTV\right) \tag{3}$$

for homebuyers, where the the mortgage-rate semielasticity of house prices is given by

$$\zeta_{p,r} = \frac{\zeta_{D,r}}{\varepsilon_{S,p} - \varepsilon_{D,p}} \leq 0 \ . \tag{4}$$

The formal proof is relegated to the appendix. Intuitively, the first order effect of the subsidy is brought about by price changes, which are generated by the adjustment in the demand for mortgage debt and housing depicted in Figure 1. With a totally elastic supply of mortgage debt the interest rate charged by lenders, r, remains fixed; thus, buyers see their borrowing cost drop from r to $r - t$, as depicted in panel (a). This is the most favorable outcome in the mortgage market for borrowers. The mortgage subsidy, then, lowers the user cost for housing services (equation (1)) increasing the demand for housing. The increase in the demand for housing, depicted by the first arrow in panel (b), depends on the mortgage rate semielasticity of house demand and the change in the mortgage rate. The second arrow in panel (b) shows how the equilibrium in the housing market is restored via an increase in house prices with the corresponding movements along the demand and supply for housing, which depend on the corresponding price elasticities. Higher housing consumption at higher house prices is financed with higher mortgage debt, so the demand for mortgage debt increases (panel (a)).

As described above the upshot of the mortgage subsidy is a reduction—one-for-one in this case—of the effective mortgage rate and an increase in house prices. These two price changes have opposite effects on buyers' welfare as shown in equation (3). This equation presents the two effects normalized by the house value and the marginal value of income (the term in front of the brackets).[12] On the one hand, lower mortgage rates benefit home buyers by lowering their mortgage interest payments (or equivalently increasing their mortgage borrowing for a given future repayment). This effect is captured by the second term inside the brackets in equation (3) and it is proportional to the LTV on the house purchase, as the benefit from lower mortgage rates only accrues to the fraction of the house financed with mortgage debt. On the other hand, higher house prices hurt buyers as it increases the house rental rate, so households give up a higher fraction of their lifetime income for house consumption. This effect is captured by the first term inside the brackets in equation (3), $\zeta_{p,r}[r(t) + \delta - \pi] \leq 0$.

As the subsidy increases house prices, house producers and homeowners benefit. This benefit equals the value of the houses they sell times the increase in house prices, given by the house price semielasticity to mortgage rates $\zeta_{p,r}$.

Note that the incidence on lenders is zero because I assumed that lenders operate a constant-return-to-scale technology and have a constant opportunity cost of funds. Allowing lenders' operational or funding costs to increase as the supply of mortgage debt increases will attenuate the reduction of the effective mortgage rate from mortgage subsidies. Intuitively, banks origination and servicing costs may increase as the volume of mortgage lending increases; or alternatively, as banks increase their demand for funds to originate more mortgages they will need to offer a higher compensations to their lenders, e.g., depositors. Allowing for these general equilibrium effects, then, is expected to attenuate the incidence on households and have a non-negative incidence on lenders.[13]

[12] The term $(1 + r(t))^2$ appears due to the assumption that mortgage subsidies increase the loaned amount, but it goes away if the subsidy is applied directly to the mortgage rate.

[13] The incidence on lenders will remain zero if the constant-return-to-scale technology assumption is maintained,

Proposition 1 is related to two previous results in the incidence literature. First, the result is related to the incidence of changes in interest rates on intertemporal consumption. A reduction in the interest rate makes current consumption cheaper incentivizing agents to increase current consumption and increase (decrease) borrowing (savings). On the other hand, a decline in interest rates generate a positive (negative) income effect for borrowers (savers). The total effect on intertemporal consumption and borrowing/savings decisions depends on both of these effects. The result in Proposition 1 can also be described in terms of substitution and income effects. A reduction in the mortgage rate, which is the relevant intertemporal price of consumption for households, reduces the user costs of present house purchases and increases the cost of future consumption. Households borrow more in order to substitute future consumption for additional housing today. But the additional house demand pushes house prices up, generating a negative income effect for household, which is proportional to the entire house purchase. Lower mortgage rates, on the other hand, generate a positive income effect for borrowers proportional to the LTV of the house purchase. These two income effects determine the incidence of the subsidy.

Second, the result of Proposition 1 is related to the incidence of non-linear taxes. Reiss and White (2006) show that the incidence of nonlinear taxes equals the traditional expression for the compensated variation plus the change in the premium paid on inframarginal units. When a house is mortgage financed a fraction, 1 − LTV, is financed with a downpayment. The user cost on the marginal units financed with debt depends on the after-subsidy mortgage rate; in contrast, the user cost for the inframarginal units financed with a downpayment depends on the opportunity cost of funds used for the downpayment.[14] A mortgage subsidy affects the house rental rate through both its effect on house prices and the user cost. On the one hand, the effect of house prices on the rental rate is given by $\zeta_{p,r}[r(t) + \delta - \pi]$, the first term in equation (3). On the other hand, the reduction of the effective mortgage rate reduces the user cost one-for-one for the marginal units financed with mortgage debt and does not affect the user cost for the inframarginal units financed with a downpayment. Thus, the change in the user cost plus the change in the premium paid on the inframarginal units is just the change in the user cost for the units financed with mortgage debt. Since the change was one-for-one the change in the user cost equals the LTV ratio, i.e., the fraction of house expenditure financed with mortgage debt, the second term in equation (3). That is, the linear mortgage subsidy acts as a non-linear subsidy on the total financing cost of housing.

Equation (4) is interesting on its own as it provides a reduced form expression, in terms of key economic parameters, for the effect of mortgage rates on house prices, specifically, the mortgage rate semielasticy of house prices $\zeta_{p,r}$. But as discussed above the identification of the mortgage

but it will be become positive if the technology is assumed to have diminishing returns to scale.

[14]The model abstract away from saving alternatives for households in period 0. But when these alternatives are considered and the household, at the margin, is substituting between savings and house expenditure, the interest rate on savings determine the opportunity cost of funds.

rate house demand elasticity $\zeta_{D,r}$ is complicated by the interplay between mortgage rates and house prices. The following Lemma establishes a relationship between the mortgage rate house demand semielasticity, the price house demand elasticity and the user costs.

Lemma 1 (Mortgage Rate House Demand Semielasticity) *In an interior solution to the household problem*

$$\zeta_{D,r} = \frac{\varepsilon_{D,p}}{r(t) + \delta - \pi} \ . \tag{5}$$

The proof consists of a simple application of the chain rule. In fact, let $R = [r(t) + \delta - \pi]p$ denote the house rental rate. Then $\zeta_{D,r} = 1/x\,(\partial x/\partial p)\,(\partial p/\partial R)\,(\partial R/\partial r) = \varepsilon_{D,p}/[r(t) + \delta - \pi]$ QED.

Lemma 1 establishes a relationship between the house price demand elasticity of housing and the mortgage rate demand semielasticity of housing: housing is more sensitive to a one percentage point reduction of the mortgage rate than a one percent reduction in house prices, as a one percentage point reduction in mortgage rates has a greater effect on the housing rental rate. Similarly, a one percentage point reduction in mortgage rates has a larger effect on the demand for housing as the user cost decreases, as it will represent a larger proportion of this cost.

Moreover, Lemma 1 allows me, under very general conditions, to obtain an estimate of the mortgage rate house demand semielasticity based on the price demand elasticity and the user cost, which can be empirically identified. In this way, Lemma 1 allows me to overcome the inherent challenge for the empirical identificiation of the mortgage rate demand elasticity, as mortgage rates affect the demand and the price for housing.

Substituting equation (5) in equation (4) I get

$$\zeta_{p,r} = \frac{1}{p}\frac{dp}{dr} = \frac{1}{r(t) + \delta - \pi}\frac{\varepsilon_{D,p}}{\varepsilon_{S,p} - \varepsilon_{D,p}} \ . \tag{6}$$

The ratio of price elasticities in the right-hand side of equation (6) corresponds to the effect on house prices from introducing a one percent house price subsidy.[15] In addition, the user cost $r(t) + \delta - \pi < 1$ so its reciprocal is greater than 1. Thus, the reciprocal of the user cost equals the house price response amplification from mortgage subsidies, relative to house price subsidies, due to the fact that the rental rate is more sensitive to changes of mortgage rates relative to changes of house prices. Furthermore, equation (6) leads to the following corollary.

Corollary 1 (Mortgage Subsidies Can Hurt Borrowers) *If the demand for housing is downward sloping with respect to the house price, $\varepsilon_{D,p} \leq 0$, and the supply for housing is upward sloping, $\varepsilon_{S,p} \geq 0$, then $-1 \leq \zeta_{p,r}[r(t) + \delta - \pi] \leq 0$ and mortgage subsidies hurt borrowers if $LTV < -\zeta_{p,r}[r(t) + \delta - \pi]$.*

The corollary is a direct consequence of Proposition 1, Lemma 1, and the fact that $\varepsilon_{S,p}, -\varepsilon_{D,p} \geq$

[15] The result follows from implicit differentiation of equation (2), considering no pre-existing house price subsidies.

0 imply that $-1 \leq \varepsilon_{D,p}/(\varepsilon_{S,p} - \varepsilon_{D,p}) \leq 0$. Corollary 1 describes a surprising result, as it establishes a sufficient condition for borrowers to be hurt by mortgage subsidies. This condition is satisfied whenever the initial LTV ratio is low enough, or the supply (demand) is very inelastic (elastic). The result is surprising as it challenges the intuition from the classic analyses of taxes and subsidies on commodities, where subsidies always weakly benefit their recipients. The difference with the classic result is a consequence of the non-linear effect of the subsidy in the user cost of homeownership. As described above, the user cost for the marginal units financed with mortgage debt depends on the effective mortgage rate, whereas the user cost for the inframarginal units financed with a downpayment depends on the opportunity cost of the funds used for the downpayment. Mortgage subsidies affect the user cost on the marginal units and thus distort the demand for housing as if housing was financed entirely with mortgage debt. In contrast, the impact of mortgage subsidies on borrowers' welfare takes into account that only a fraction of the house is financed with mortgage subsidies (equation (3)). In fact, the benefit from lower effective mortgage rates only accrues to the fraction financed with mortgage debt, whereas the negative effect from higher house prices accrues to the entire house.

House price responses described in equation (6) are amplified by the adjustment in LTV incentivized by mortgage subsidies. In order to show how this amplification channel operates it is useful to consider the problem of a homebuyer who is constrained by an LTV limit. This is the case, for instance, when the marginal utility of period 1 consumption is bounded and period 0 income y is low enough such that the natural borrowing limit $c \geq 0$ binds. In this case, mortgage borrowing equals $(1 + \pi - \delta)px$ and the $\text{LTV} = (1 + \pi - \delta)/(1 + r(t))$, which is fixed for any level of the mortgage subsidy t. Given the borrowing constraint, the demand for housing is given by $(1 + r(t))y/[(r(t) + \delta - \pi)p]$, from where it follows that $\zeta_{D,r} = \varepsilon_{D,p}\text{LTV}/[r(t) + \delta - \pi]$. Given that $\text{LTV} < 1$ this attenuates the semielasticity of house prices with respect to interest rates. It is interesting to note that in this case of an LTV limit, the incidence on homebuyes is always non-negative—as in the classic case. In this case, the marginal and average effects of mortgage subsidies are aligned. This case highlights that it is the LTV increase generated by the mortgage subsidy that opens the scope for the subsidy to hurt homebuyers, who are the intended beneficiaries of the subsidy.

The increase of LTVs caused by mortgage subsidies in the model could be thought of as an upper bound, as in the model the only additional source of funds to finance the increase in housing expenditure are mortgages. However, in practice home buyers might respond by adjusting their overall portfolio and liquidate some other assets to finance the additional house expenditure. In addition, as buyers increase their LTV, lenders might increase the interest rate to protect themselves against higher expected losses, or risk averse home buyers might refrain from taking additional leverage when they face house price or income risk. These channels suggest that the increase in

LTV will be attenuated, but the evidence points to increases (decreases) in LTV when mortgage subsidies are increased (decreased), lending support for this implication of the model.[16]

2.3 Efficiency Costs from Mortgage Subsidies

What is the efficiency loss from the distortions introduced by mortgage subsidies, when these subsidies affect effective mortgage rates and house prices? To answer this question, here I derive the classic excess burden formula for mortgage subsidies that parallel the derivations in Auerbach (1985). The expression I obtain can be represented graphically as the area between the supply and demand functions and the wedge introduced by the subsidy in the mortgage market: the Harberger triangle.

To calculate the excess burden generated by mortgage subsidies additional assumptions are needed. One necessary assumption is that mortgage subsidies only affect house prices in period 0, whereas house prices in period 1 are fixed. This assumption is needed because the house price in period 1 is not determined by the equilibrium of supply and demand. Similar results would obtain if future price effects are considered together with all the determinants of house demand and supply in future periods. Another set of assumptions are required to carry on the calculations and are drawn from the literature to facilitate comparison with the classic results (see Auerbach 1985, for a discussion of the techniques and assumptions needed for these calculations). First, profits from house producers are rebated lump sum to households. This assumption together with accounting for the welfare change of homeowners effectively makes the excess burden measure independent from the redistribution of resources from households to firms (or firms to households). Second, preferences do not exhibit income effects, i.e., preferences take the following quasilinear form, $u(x) + c$. This assumption is necessary to make the triangle delimited by the uncompensated demand function an accurate measure of welfare, but it can be relaxed obtaining similar results, as I discuss below. This assumption also allows to aggregate the welfare effects across households, fixing the marginal utility of income.[17]

Let v denote the indirect utility function and $e(p, r, v)$ denote the expenditure function given a house price p, a mortgage rate r, and an indirect utility v.[18] I follow Davidoff, Brown, and Diamond (2005) and specify the expenditure minimization problem as the problem to minimize period 0 expenditure to achieve the level of indirect utility v and imposing the budget constraint

[16] For the effect of mortgage subsidies on LTVs see Follain and Dunsky (1997), Ling and McGill (1998), Dunsky and Follain (2000), and Hendershot, Pryce and White (2002).

[17] In addition, recall that the government finances itself with lump sum taxes in period 0. Alternatively, it can be assumed that it has some other non-distortionary forms of income.

[18] This notation allows to consider the two variational measures of welfare change for consumers in the case with non-zero income effects. In fact, if v corresponds to the indirect utility in the equilibrium at the original (subsidized) prices, then households welfare changes are measures by the compensated (equivalent) variation.

in period 1 as a constraint. Under these assumptions the excess burden of introducing a mortgage subsidy, t, denoted by $EB(t)$, corresponds to the loss in consumer surplus (which includes the loss in firms' surplus), plus the loss for homeowners, minus the change in government revenues.

$$EB(t) = e(p(t), r(t), v) - \pi(t) - e(p(0), r(0), v) + \pi(0) - (p(t) - p(0))h + G(p(t), r(t), t, y) ,$$

where $G(p, r, t, y)$ denote the government expenditure on mortgage subsidies, equal to $t\, m(p, r, y)$.[19]

A second order Taylor approximation of $EB(t)$ yields the following result.

Proposition 2 (Efficiency Cost from Mortgage Subsidies) *The efficiency loss from mortgage subsidies equals*

$$EB(t) = \frac{1}{2}\, t\, \Delta m \,. \tag{7}$$

This result has an intuitive explanation that can be better described using Figure 2. Mortgage subsidies reduce the effective mortgage rate faced by borrowers by t, increasing the demand for mortgage debt. As the model assumptions ensure that the interest rate offered by lenders remains fixed at $r = r_f + \rho$, the effective mortgage rate faced by borrowers becomes $r - t$. Thus, the demand for mortgage debt increases until the difference between the original mortgage demand $M(0)$ and mortgage supply equals t, as depicted in Figure 2. This increases borrowers' surplus by the area *abde*. The government needs to finance a subsidy t for every unit of mortgage credit taken by borrowers, for a total cost of $t\, m(t)$ equal to the area *acde*. This creates a deadweight loss equal to the area of the triangle *bcd*, or $t\, \Delta m/2$. This is the Harberger deadweight loss triangle of mortgage subsidies from the distortion introduced in the mortgage market.

In addition, in the housing market the increase in demand for housing raises prices from $p(0)$ to $p(t)$. This price increase creates a loss for homebuyers equal to the area *abcd*, which is exactly the gain for sellers, i.e., home producers and homeowners (Figure 2). That is, the effect of the mortgage subsidy on the housing market is a zero-sum redistribution between buyers and sellers that creates no additional deadweight loss.[20] In sum, in the mortgage market the subsidy introduces an inefficient distortion, whereas in the housing market the subsidy generates a wealth redistribution through the house price, without contributing to additional inefficiency losses.

The deadweight loss depends on the sensitivity of mortgage borrowing to the subsidy, Δm, which is comprised of two parts. First, as effective mortgage rates fall homebuyers increase their demand for housing and thus they increase their demand for mortgage debt. Second, as I emphasize in this paper, as effective mortgage rates fall house prices increase affecting mortgage demand in

[19]Note that in the general case with income effects, the excess burden calculations are done considering the compensated demand functions, so the government subsidy expenditure will depend on the compensated mortgage demand.

[20]Note that the change in buyers' welfare is the area under the supply function S, as opposed to the area under the demand function.

two ways. Higher house prices increase housing expenditure, increasing the demand for mortgage debt. In addition, higher house prices reduce housing and mortgage demand. So the increase of housing and mortgage demand is attenuated by the increase in house prices. All in all, the first order effect of lower effective mortgage rates is to increase the demand for mortgage debt by $\Delta m \approx -px\left(\varepsilon_{D,p}\zeta_{p,r} + \zeta_{D,r} + \zeta_{p,r}\right)\Delta t$.[21] Therefore, the efficiency loss is larger when house demand is more elastic to mortgage rates, i.e., as $\zeta_{D,r}$ is larger in absolute value. In contrast, the efficiency loss is larger when house demand is more inelastic to house prices. Intuitively, as the demand for housing becomes less sensitive to house prices, there is a smaller offset from the reduction of house demand as house prices increase. The effect of the mortgage rate semielasticity of house prices $\zeta_{p,r}$ depends on the price elasticity of house demand $\varepsilon_{D,p}$: when the demand for housing is more (less) than unit elastic, the efficiency loss is larger (smaller) when the semielasticity of house prices to mortgage rates is more inelastic.

To derive Proposition 2 I assumed that the demand for houses does not display income effects. This assumption is sometimes justified on the grounds that the market being studied is small, making income effects negligible (Vives, 1987). In contrast, for most households housing is an important expenditure category and housing constitute an important fraction of financial wealth, making income effects relevant. As we know from the classic results in public finance, income effects can be considered in the analysis by considering the compensated demand functions for housing and mortgage debt and by considering that the form of compensation take a particular form (Auerbach 1985). In fact, it is possible to extend the result of Proposition 2 assuming that compensation takes the form of period 0 income. In this case, Δm, the uncompensated response of mortgage borrowing, needs to be replaced in equation (7) by, $\Delta\hat{m}$, the compensated response of mortgage borrowing.

To calculate the response of the compensated demand for mortgage debt, I use a "hat" ("ˆ") to denote the variables corresponding to the compensated demand functions. For instance, $\hat{\varepsilon}_{D,p}$, and $\hat{\zeta}_{D,r}$ denote, respectively, the price and mortgage rate compensated house demand elasticities. Similarly, let $\varepsilon_{M,p}$, $\zeta_{M,r}$, $\hat{\varepsilon}_{M,p}$, and $\hat{\zeta}_{M,r}$ denote the uncompensated and compensated house price and mortgage rate elasticities of mortgage demand. Then, the compensated response of mortgage demand can be approximated by $\Delta\hat{m} \approx -m\left(\hat{\varepsilon}_{M,p}\hat{\zeta}_{p,r} + \hat{\zeta}_{M,r}\right)\Delta t$. Where $\hat{\zeta}_{p,r}$ corresponds to the mortgage rate semielasticity of house prices, when homebuyers are being compensated by the income effect of price changes, i.e., $\hat{\zeta}_{p,r} = \hat{\zeta}_{D,r}/\left(\varepsilon_{S,p} - \hat{\varepsilon}_{D,p}\right)$. The response of the compensated demand for mortgage debt, $\Delta\hat{m}$, can be expressed in terms of the demand elasticities for *housing* using the Slutzky equations for mortgage demand and the relationship imposed on the demand

[21]In fact, from equation (4) it follows that $-px(\varepsilon_{D,p}\zeta_{p,r} + \zeta_{D,r}) = -px\zeta_{D,r}\varepsilon_{S,p}(\varepsilon_{S,p} - \varepsilon_{D,p})^{-1} > 0$. That is, the demand for housing increases as the effect of lower mortgage rates dominates the counterbalancing effect of higher house prices. In addition, housing expenditure increases by $-px\zeta_{p,r} > 0$.

elasticities by the period $t = 0$ budget constraint for homebuyers.[22]

Finally, suppose there is a preexisting subsidy t_0 and it is changed to t_1. Let $\Delta m_1 = m(t_1) - m(t_0)$ and use the same notation for other variables, for instance, $\Delta t_1 = t_1 - t_0$. Then, it can be shown that the efficiency loss is given by the Harberger trapezoid formula $EB(\Delta t_1) = t_0\, \Delta m_1 + 1/2\, \Delta t_1\, \Delta m_1$.

The formula of Proposition 2 generalizes the classic Harberger formula for excess burden to the case of mortgage debt, when house prices adjust in response to the mortgage subsidy. Laidler (1969) shows that the classic Harberger triangle formula can be used to measure the efficiency cost of housing subsidies under the assumptions of perfect capital market—so the LTV ratio is an irrelevant statistic—and fixed house prices. As in my analysis, Laidler considers that housing demand is a function of the homeownership rental rate, and he maps tax code provisions into their effect on the rental rate. Using my notation Laidler's excess burden formula can be expressed as $1/2\, \Delta\hat{x}\, \Delta R$.[23] In this case mortgage demand is undetermined and we can assume that it equals the value of housing expenditure, i.e., $\hat{m} = p\hat{x}$, so $\Delta\hat{m} = p\Delta\hat{x}$. Furthermore, when house prices are fixed changes to the rental rate are caused by changes in the user cost. Let u denotes the user cost of homeownership, then $\Delta R = p\Delta u$, with $\Delta u = t$. Thus, we can express Laidler's excess burden as $1/2\, t\, \Delta\hat{m}$. That is, we recover my expression for the excess burden. The difference with Laidler's formula is that in my analysis mortgage demand will change in response to changes in mortgage rates and house prices. Analytically, I approximate the change in the compensated mortgage demand by $\Delta\hat{m} \approx -m\, (\hat{\varepsilon}_{M,p}\hat{\zeta}_{p,r} + \hat{\zeta}_{M,r})\, \Delta t$, whereas assuming fixed house prices ($\hat{\zeta}_{p,r} = 0$) the change in the compensated demand for mortgages $\Delta\hat{m}$ is approximated by $-m\, \hat{\zeta}_{M,r}\, \Delta t \geq 0$, ignoring the attenuating effect of house price changes, $-m\, \hat{\varepsilon}_{M,p}\hat{\zeta}_{p,r}\, \Delta t \leq 0$.

3 Data

In this section I describe the data used to measure the effect of eliminating MID. This description precedes the generalization of the previous results, as the data availability will inform the modeling choices to generalize these results.

Mortgage level information. I use mortgage level information from McDash Analytics (formerly LPS) and Equifax Credit Risk Insight Servicing (CRISM). The details of these data sources and calculations are provided in Appendix B.

From McDash Analytics I obtain information on mortgage term, house value, LTV ratio, mortgage interest rate, and the zip code of the property. I consider individual mortgages originated

[22] In fact, from the Slutzky equtions $\hat{\varepsilon}_{M,p} = \varepsilon_{M,p} + pxy^{-1}\varepsilon_{M,y}$ and $\hat{\zeta}_{M,r} = \zeta_{M,r} + pxy^{-1}LTV(1+r(t))^{-1}\varepsilon_{M,y}$, where $\varepsilon_{M,y}$ denotes the income elasticity of (uncompensated) mortgage demand. In addition, differentiating the period 0 budget constraint $\varepsilon_{M,p} = LTV^{-1} + LTV^{-1}\varepsilon_{D,p}$, $\zeta_{M,r} = (1+r(t))^{-1}LTV^{-1}\zeta_{D,r} + (1+r(t))^{-2}$ and $\varepsilon_{M,y} = \varepsilon_{D,y}LTV^{-1} - pxy^{-1}LTV^{-1}$.

[23] Laidler (1969) assumed away income effects and worked with the uncompensated response of housing demand. But the literature that have built on his result has considered income effects, so I consider the more general case.

between 2010 and 2015, which corresponds to the longest sample excluding the financial crisis of 2007-2009.[24] I restrict attention to fixed mortgages—i.e., fixed monthly payment and fixed term—which have a first-lien on the property and with the most common mortgage terms (10, 15, 20, 25, and 30 years).[25,26] My final sample comprise 17.6 million mortgages.

From CRISM I obtained credit bureau data six months prior to the origination of the mortgage, which I use to identify first-time homebuyers. CRISM matches credit bureau data from Equifax with mortgage records in McDash. A mortgage is identified as a first time homebuyers if the mortgage was reportedly used to purchase a property (as opposed to refinance it) and the borrower did not have any opened mortgage account in his credit history over the last six months. Using this definition I identify 18.5% of mortgages that correspond to first-time buyers (Table 1).

Table 1 provides descriptive statistics at the mortgage level. The average mortgage rate and LTV ratio in the sample are 4.2 and 77 percent, respectively. Table B.2 presents descriptive statistics for mortgage rates and LTV ratios separately for first-time buyers and homeowners by mortgage term. As expected, mortgage rates and LTV ratios are higher (lower) for first-time buyers (homeowners), with average mortgage rates and LTV ratios of 4.3 (4.1) and 90 (74) percent, respectively. Also as expected, the mortgage rate and the LTV increase with the term of the mortgage. The latter probably reflecting a desire by both borrowers and lenders to keep income-to-debt-service ratios low.

To handle the heterogeneity in mortgage chacteristics in the McDash data it will be useful to introduce the following notation. Let $i \in I$ index mortgage borrowers in my sample and consider that each borrower i is offered a different after-subsidy mortgage rate $r_i(t_i)$ and borrows using an initial LTV ratio LTV_i and a mortgage term of T_i years.[27]

Elasticities. I draw from available studies and use Lemma 1 to calibrate the relevant elasticities.

Saiz (2010) uses land topology-based estimates of land availability to provide estimates of the price elasticity of house supply for 269 Metropolitan Statistical Areas (MSAs), over 10-year periods. I denote with $\varepsilon_{S,p,j}$ the price elasticity of house supply in metropolitan area j. The estimated values range from as low as 0.6 to as high as 12.1, and have a population-weighted average of 1.8.

The empirical literature suggests that the price elasticity of housing demand is close to -1, e.g., Rosen (1985) or Davis and Ortalo-Magne (2011). So I set $\varepsilon_{D,p} = -1$.

[24] Granted, this is a special period following a large financial crisis. The S&P/Case-Shiller U.S. National Home Price Index of house prices fell between July 2006 and February 2012 by 27%, and was 5% below its July 2006 peak in December 2015. But this period seems the most adequate to characterize the effect of the elimination of MID if it where to be implemented today.

[25] Second-lien mortgages have not been common after the financial crisis.

[26] Additionally, I restrict attention to the zip codes in metropolitan areas for which I have information for the price house supply elasticity (see Appendix B).

[27] In the model of section 2 borrowers with identical preferences will choose different LTV ratios, if they borrow at different mortgage rates $r_i(t_i)$ or have different income levels y_i.

To calibrate the mortgage rate semielasticity of demand, $\zeta_{D,r}$, I use the relationship of this elasticity and the price elasticity of demand and the user cost established in Lemma 1. The price elasticity of demand was set to -1 and to estimate borrowers' user cost I proceed as follows. The mortgage data from McDash provides the mortgage rate for each borrower. The other terms of the user cost, namely $\delta - \pi$ in the model of section 2, are calibrated assuming that they represent *all* the non-mortgage rate components of the user cost, some of which I have abstracted away in the model for simplicity. I follow Poterba (1992) and Himmelberg et al. (2005) and consider the following additional component of the user cost: τ_y the marginal income tax, τ_p property taxes, and ϕ the risk premium. Let i denote the nominal mortgage rate, which equals the real mortgage rate r plus the (expected) rate of inflation Π. Then I can express the real user cost, accounting for the deductibility of mortgage interest and property taxes, as $r - \tau_y i + (1 - \tau_y)\tau_p + \delta - \pi + \phi$. The values for these parameters are set following Himmelberg et al. (2005): $\tau_y = 25\%, \Pi = 2\%, \tau_p = 1.5\%, \delta = 2.5\%, \pi = 1.8\%$, and $\phi = 2\%$. With a slight abuse of notation I denote the real user cost by $r_i - \tau_y i_i + \delta - \pi$, and I set $\delta - \pi = (1 - \tau_y)\tau_p + \delta - \pi + \phi = 3.8\%$. Considering my sample average nominal mortgage rate of 4.2% and a 2% inflation, I obtain a real mortgage rate of 2.2% and a subsidy from MID of about 100 basis points. These parameter values give a real user cost of housing of 5% (Table 1).

Lemma 1 can be restated considering the deductibility of mortgage interest in the user cost of homeownership. In this case, the relationship between the mortgage rate demand semielasticity and the house price demand elasticity is given by

$$\zeta_{D,r,i} = \frac{\varepsilon_{D,p}(1 - \tau_y)}{r_i - \tau_y i_i + \delta - \pi} . \tag{8}$$

This relationship can be used to compute the mortgage rate semielasticity of house demand at the individual level. Table 1 present descriptive statistics of my estimates for this elasticity. The sample average equals -15.3, with individual estimates displaying significant heterogeneity ranging from -41 to -5.

Finally, let γ be the housing expenditure share, corresponding to the rental rate of housing over income, and let $\varepsilon_{D,y}$ denote the income elasticity of house demand. Following Poterba (1992) and Davis and Ortalo-Magne (2011) I set $\gamma = 0.25$, and following Poterba (1992) I set $\varepsilon_{D,y} = 0.75$.

4 Estimates of the Effects of Eliminating MID

In this section, I present my estimates of the effects of eliminating mortgage interest deductions (MID) on house prices, individual welfare, and efficiency gains. I estimates these effects for 269 metropolitan areas in the U.S.[28] I begin in section 4.1 with a description of how these effects are measured using the data described above. Section 4.2 presents my estimates for the effect on house prices from a change in effective mortgage rates and compares them with other estimates. Finally, section 4.3 presents my estimates of the distributional impact and efficiency gains of eliminating MID for the 269 metropolitan areas in my sample.

4.1 Measurement of Welfare Effects

The characterization of the incidence and the efficiency loss of mortgage subsidies presented in section 2 was done in the simplest framework to highlight the economic mechanisms and the economic intuition. In contrast, in this section I generalize these results to measure the effects of eliminating MID incorporating the relevant features of the data described in section 3.

Assuming that the marginal tax rate is τ_y and that the household deducts mortgage interest from her income tax, the effective mortgage rate is reduced by $\tau_y i_i$. Arguably these are strong simplifying assumptions, as marginal tax rates vary substantially by households depending on their income and some households may opt for the standard deduction to the income tax. Nonetheless, given that the McDash and CRISM data do not contain income or other relevant tax-related information, I assume that the marginal tax rate $\tau_y = 25\%$ for all households and that all households itemize their deductions.

These assumptions will affect the estimated house prices and welfare effects. For the house price effects estimated from the elimination of MID it is expected that they will be amplified, as I assume that non-itemizers also reduce their demand in response to the policy change. This bias is attenuated as households are effectively weighted by their share of housing consumption and households living in more expensive housing units tend to itemize. Moreover, my estimates of the semilasticity of house prices with respect to mortgage rates are immune to this bias as they consider an hypothetical change in effective mortgage rates. For the distributional effect of eliminating MID, I will attribute the negative effect of higher effective mortgage rates for all households although non-itemizing buyers (homeowners) will only benefit (suffer) from lower house prices. For the efficiency loss, I will overestimate the aggregate effect as for some households the elinination of MID will have no effect on effective mortgage rates. This bias goes against my result that the aggregate efficiency gains from eliminating MID are small given the offset in the distortion of mortgage demand generated by the decline in house prices.

Despite the simplifying assumption that marginal tax rates are the same across households, the actual subsidy from MID will vary across households reflecting the differences in nominal mortgage rates. To handle this heterogeneity analytically I introduce the following notation. Let

[28]The estimates for the 269 metropolitan areas are available at http://www.federalreserve.gov/econresdata/feds/2016/files/feds2016081data.csv.

$\varphi \in [0,1]$ denote the fraction of mortgage interests that can be deducted, so the effective real mortgage rate is $r_i(\varphi) = r_i - \varphi \tau_y i_i$, when a fraction φ of mortgage interests can be deducted. Then, $\varphi = 1$ represents the current condition, where all mortgage interests can be deducted, whereas $\varphi = 0$ represents the elimination of MID. In addition, I denote by $\Delta r_i = r_i(0) - r_i(1)$ the change in the mortgage rate—or any other variable—from the elimination of MID. Now, I can present the simple formulas for the effect of eliminating MID on house prices, incidence, and efficiency cost.

House price effects. In the data different regions display a different price elasticity of supply and households (first-time buyers and owners) borrow using mortgage contracts with different characteristics. I assume that each metropolitan area corresponds to a segmented housing market with no household mobility in response to MID, so each metropolitan region can be considered separately. Let I_j be the set of households in metropolitan region j, and ω_i be household's i share of housing consumption in the region. The aggregate demand for housing is given by $\sum_{i \in I_j} x_i(p_j, r_i(t_i), y_i)$. Then, fully differentiating the house market clearing condition for region j with respect to the mortgage rate, I obtain the following expression for the mortgage rate semielasticity of house prices in region j

$$\zeta_{p,r,j} = \frac{\sum_{i \in I_j} \omega_i \zeta_{D,r,i}}{\varepsilon_{S,p,j} - \varepsilon_{D,p}} . \tag{9}$$

Similarly, the effect on house prices in region j from removing MID can be approximated by

$$\frac{\Delta p_j}{p_j} \approx \frac{\sum_{i \in I_j} \omega_i \zeta_{D,r,i} \tau_y i_i}{\varepsilon_{S,p,j} - \varepsilon_{D,p}} . \tag{10}$$

In Section 4.2, I provide metropolitan level estimates of the mortgage rate semielasticity of house prices using equation (9) and of the house price decline implied by the elimination of MID using equation (10).

Incidence. One feature of the data is that house investments and mortgage borrowing extend over many years. Here, I describe the assumptions made to extend Proposition 1 to a multiperiod setting. First, I assume no transaction costs. Then, the incidence of mortgage subsidies will only depend on the future trajectory of housing and mortgage demand, and will be independent of the moves a households makes in the period. If a household moves from one house to an identical house (as measured by their effective housing units represented by x in the model) and maintain the same path for mortgage balances, this move will have no effect on the incidence of mortgage subsidies.

Second, I assume that the household does not adjust its housing or mortgage demand after the origination of her mortgage. That is, the household let its housing stock to depreciate and pays off her mortgage according to the schedule implied by the original fixed mortgage.[29]

[29]The assumption of a fixed housing stock is similar to assuming that the household pays the required maintenance costs to keep its housing stock fixed, except for the timing of maintenance costs.

Third, I assume that after the household pays off her mortgage she sells the house and consume the proceeds. Buying another house will make the incidence to depend on the adjustment to the housing stock, which I cannot observe in the data. This assumption affects the estimates depending on the future path of the housing stock and mortgage debt. For households that do not purchase another house the effect of this assumption depends on the difference between the actual future sale date versus the date when the mortgage is paid off. For households that remain in the house after the mortgage debt was scheduled to be paid off, the harm from selling the house at a lower price is front loaded making the estimated welfare effect of the subsidy worse for borrowers. In contrast, if the house is sold before the mortgage termination date the adverse effect of lower future house prices is back loaded in my calculations and bias the estimates making them more beneficial for households. But, note that in the latter case the mortgage will be prepaid and the household will forego the reduction in effective mortgage rates considered in my calculations, making the welfare estimates less beneficial for households.

I make the same assumptions to model the behavior of homeowners. The only distinction between homeowners and first-time buyers is that the former already own their optimal housing stock, so the change in house prices only affects these households when they sell their house.

Then, under my assumptions it is possible to establish the following result.

Proposition 3 (Incidence over multiple periods) *The incidence of a permanent elimination of MID, equals zero for lenders, $p_j z_j(\Delta p_j/p_j)$ for house producers,*

$$\Delta V_i = u_c p_j x_i \left(-\phi_p(r_i(1), T_i)\, \frac{\Delta p_j}{p_j} - \phi_m(r_i(1), T_i)\, LTV_i \right) \tag{11}$$

for household i in metropolitan area j, where $\Delta p_j/p_j < 0$ is given by equation (10) and the price and LTV multipliers are, respectively, given by

$$\phi_p(r_i(\varphi), T_i) = \begin{cases} 1 - (1 - r_i(1) - \delta + \pi)^{T_i} & \textit{for first-time buyers} \\ -(1 - r_i(1) - \delta + \pi)^{T_i} & \textit{for homeowners} \end{cases}$$

$$\phi_m(r_i(\varphi), T_i) = \frac{\tau_y i_i}{12(1 + r_i(\varphi))^{\frac{11}{12}}} \left(\frac{1}{(1 + r_i(\varphi))^{\frac{1}{12}} - 1} - \frac{12 T_i}{(1 + r_i(\varphi))^{\frac{1}{12}} \left[(1 + r_i(\varphi))^{T_i} - 1 \right]} \right).$$

It follows that the welfare effect of the elimination of MID can be expressed as the sum of two terms: one term representing the impact of the decline in house prices, and another term representing the burden of higher effective mortgage rates, which depends on the LTV ratio at origination. The magnitude of these two effects depends on the mortgage rate, the other components of the user cost, and the mortgage term (assumed to equal the duration of the house investment). A longer mortgage term increases the present value of MID, as it increases the present value of interest payments. On the other hand, longer house investments reduce the present value loss of selling the house at a lower price in the future. Note that the price multiplier is positive for first-time buyers ($\phi_p > 0$) and is negative for homeowners ($\phi_p < 0$), reflecting the differential impact that the permanent house price decline have on these two group of households. A reduction in house prices benefit first-time buyers as the benefit from purchasing their houses at a lower price outweigh the present value loss from selling these house units at a lower price in the future. On the contrary, under my assumptions, homeowners are only affected negatively from a lower house price when they sell their house units in the future. Table 2 presents descriptive statistics of the price and LTV multiplier for owners and buyers depending on their mortgage term.

Note that equation (11) makes the incidence on households comparable when they purchase houses of different values. In fact, the term in the RHS inside the parenthesis in this equation measures the incidence as a fraction of the house value. In Section 4.3, I use this equation to provide estimates of the incidence of MID on homeowners and first-time homebuyers.

Efficiency Costs. To measure the efficiency losses I need to maintain some of the assumptions made in Section 2.3. In particular, I consider the same two period framework and maintain the assumption that house prices in period 1 are fixed. Given that the calculations of efficiency losses abstract from distributional effects, I abstract from the distinction between owners and first-time buyers. I assume that all households have to buy their desire housing stock and at the same time are entitled to the proceeds from the sale of the existing stock of housing and the profits made by house producing firms. In contrast, I relax other assumptions that are not needed to calculate the efficiency cost in practice. First, I consider income effects in the demand for housing. Second, I consider that in each metropolitan region there are heterogenous households who borrow using different mortgage rates and LTV ratios, as observed in the data.

Let $\pi_j(\varphi)$ be the profit of house producers in metro area j when the fraction of mortgage interest that can be deducted is φ, let h_j be the existing housing stock in metro area j, and let $t_i(\varphi)$ be the period 0 mortage subsidy when a fraction φ of mortgage interest can be deducted.[30] Using this notation the excess burden of eliminating the MID in metropolitan area j can be expressed as

$$\begin{aligned} EB_j(1,0) = &\sum_{i \in I_j} e_i(p_j(0), r_i(0), v_i) - \pi_j(0) - p_j(0)h_j \\ &- \sum_{i \in I_j} e_i(p_j(1), r_i(1), v_i) + \pi_j(1) + p_j(1)h_j + G(p_j(0), r_{I_j}(0), 0, e_{I_j}(p_j(0), r_i(0), v_i)) \,, \end{aligned}$$

where variables with subscript I_j denote the vector of values for all households i in metro area j, for instance, $r_{I_j} = \{r_i\}_{i \in I_j}$; and $G(p_j, r_{I_j}, \varphi, e_{I_j}(p_j, r_i, v_i))$ denotes the government expenditure on

[30] From the identity $q_i + t_i(\varphi) = (1 + r_i - \varphi\tau_y i_i)^{-1}$ it follows that $t_i(\varphi) = \varphi\tau_y i_i(1 + r_i)^{-1}(1 + r_i - \varphi\tau_y i_i)^{-1}$.

mortgage subsidies, equal to $\sum_{i\in I_j} t_i\ m_i(p_j, r_i, e_i(p_j, r_i, v_i)) = \sum_{i\in I_j} t_i\ \hat{m}_i(p_j, r_i, v_i)$, where the last equality uses the identity between the uncompensated and compensated demand functions.

A second order Taylor approximation around $\varphi = 1$ gives the Harberger triangle formula[31]

$$EB_j(1,0) \approx \frac{1}{2}\sum_{i\in I_j}[\hat{m}_i(0) - \hat{m}_i(1)]t_i(1) = \frac{1}{2}\sum_{i\in I_j}\Delta\hat{m}_i\, t_i(1)\ , \tag{12}$$

where $\hat{m}_i(\varphi) = \hat{m}_i(p_j(\varphi), r_i(\varphi), v_i)$ is the compensated mortgage demand function.

To evaluate this formula in the data I use that the change in the compensated mortgage demand can be approximated by $\Delta\hat{m}_i \approx \hat{m}_i(1)\,[\hat{\varepsilon}_{M,p,i}\,\Delta\hat{p}_j/p_j + \hat{\zeta}_{M,r,i}\,\Delta r_i]$, where $\Delta\hat{p}_j/p_j$ corresponds to the decline in house prices in region j, when households are compensated for the price changes induced by the elimination of MID. The change in the compensated mortgage demand can be expressed in terms of the house demand elasticities using the Slutzky equations and the relationship imposed by the period 0 budget constraint (see footnote 22). In fact, combining these equations I obtain that $\hat{\varepsilon}_{M,p,i} = \varepsilon_{D,p}/LTV_i$, as the income compensation for mortgage demand cancels with the effect of house prices on house expenditure, and $\hat{\zeta}_{M,r,i} = [\zeta_{D,r,i}/LTV_i + r_i(\varphi)/(1 + r_i(\varphi))]/(1 + r_i(\varphi))$, where the last term collects the effect of the income compensation and the effect of mortgage rates on mortgage interest expenses. It follows that

$$\Delta\hat{m}_i \approx p_j x_i\Bigg[\underbrace{(1 + r_i(1))\varepsilon_{D,p}\frac{\Delta\hat{p}_j}{p_j}}_{\text{house price effect}} + \underbrace{\left(\zeta_{D,r,i} - \frac{r_i(1)LTV_i}{1 + r_i(1)}\right)\tau_y i_i}_{\text{mortgage rate effect}}\Bigg]\ . \tag{13}$$

That is, the distortion in the (compensated) mortgage demand can be expressed as the sum of two effects. The house price effect, which reflects that as house prices decrease when the MID is eliminated ($\Delta\hat{p}_j < 0$) the (compensated) demand for mortgage debt increases ($\varepsilon_{D,p} < 0$). On the other hand, the mortgage rate effect captures that as the effective mortgage rate increases, the demand for mortgage debt declines (recall that $\zeta_{D,r,i} < 0$). One important takeaway from decomposing the distortion of mortgage demand into these two terms is that the house price effect—which is positive—attenuates the distortion of mortgage rates in mortgage demand, which will reduce the efficiency loss brought about by mortgage subsidies. In Section 4.3, I use equations (12) and (13) to provide estimates of the efficiency gains from eliminating MID.

The main difference between equations (12) and (13) with previous studies is the presence of the house price effect. For instance, following Laidler (1969) and Rosen (1979), Poterba (1992) measures the excess burden of mortgage subsidies using $EB = 1/2\,\Delta\hat{x}\,\Delta R$. As argued above this formula coincides with my generalized formula when house price effects are ignored. But there are

[31]Note that Harberger's trapezoid formula with preexisting MID turns into a triangle formula once I consider the total elimination of MID.

other differences between previous work and mine regarding the sample considered and the way key elasticities are calibrated. Therefore I focuss on the difference for the measurement of excess burden caused by price effects, as described in equation (13), to compare my estimates with the previous literature.

4.2 Estimates of the Effect of Mortgage Rates on House Prices

Using the previously derived formulas, together with the data described in section 3, I can estimate the sensitivity of house prices to mortgage rates in the 269 metropolitan areas in my sample. In fact, equations (9) and (10) provide, respectively, estimates for metropolitan area j of the mortgage rate semielasticity of house prices, $\zeta_{p,r,j} = 1/p_j(dp_j/dr)$, and of the decline in house prices from the elimination of MID, $\Delta p_j/p_j$. These equations show that the effect on house prices differs across metropolitan areas given differences in the price elasticity of supply, $\zeta_{S,p,j}$, and the (house-value-weighted) average mortgage rate semielasticity of demand, $\zeta_{D,r,j} = \sum_{i \in I_j} \omega_i \zeta_{D,r,i}$.

Table 3 shows that while the supply elasticity displays significant variation across metropolitan areas, the average mortgage rate semielasticity is very stable across regions, despite the individual mortgage-rate semielasticities of house demand displaying considerable heterogeneity (Table 1). In fact, the price supply elasticity has a (house-value-weighted) mean of 1.5 and a standard deviation of 0.9.[32] In contrast, the mortgage rate demand elasticity has a mean of −15.4 and a standard deviation of only 0.1. Thus, the sensitivity of house prices to interest rates is determined primarily by the price house supply elasticity. Table 3 shows that the estimated (house-value-weighted) average decline in house prices from eliminating MID would be 6.9%. Similarly, the estimated (house-value-weighted) average mortgage rate semielasticity of house prices is −6.9. That is, the decline in house prices from eliminating MID is about the same magnitude as predicted by a 1 percentage point increase in mortgage rates. This reflects that under the assumption that the marginal tax rate τ_y equals 25% and with an average nominal mortgage rate of 4.2% in my sample, the MID amount to a reduction in the effective mortgage rate of about 1 percentage point. This semielasticiy of house prices ranges from −9.6 in Miami, Florida, where the price elasticity of supply is 0.60, to −1.2 in Pine Bluff, Arizona, where the supply elasticity is 12.2.

Figure 3 plots the estimated decline in house prices from eliminating MID for the 269 metropolitan areas in my sample. The figure shows that my estimates for the decline in house prices depends primarily on the supply elasticity, and that they are well approximated by $-15.4/(\varepsilon_{S,p,j}+1)$. This expression corresponds to equation (10) assuming: (i) an effective decline in mortgage rates of 1 percentage point; (ii) a mortgage-rate house demand semielasticity equal to the average of −15.4 (Table 3); and (iii) a price house demand elasticity equal to −1, as I have assumed. This

[32]The household-weighted average supply elasticity is 1.74 in my sample, in line with the household-weighted average reported by Saiz (2010) of 1.75.

approximation works well given that the mortgage-rate house demand semielasticity, $\zeta_{D,r,j}$, varies very little at the MSA level (Table 3).[33]

My estimates of the mortgage rate semielasticity of house prices $\zeta_{p,r,j}$ can be compared to direct estimates from empirical studies. The empirical evidence is broadly in line with my average estimate of -6.9. One strand of the literature studies the effect on house prices of changes in mortgage rates, i.e., the *price* of mortgage credit. Glaeser, Gottlieb and Gyourko (2012) regress an aggregate house price index of repeated sales against the 10-year Treasury bond rate and estimate a house price semielasticity to this interest rate of -6.8. But as they acknowledge, this estimate might be biased by the endogeneity of interest rates. Adelino et al. (2014) use changes in the conforming loan limit to measure the effect of lower mortgage rates on house prices. They estimate a house price semielasticity to mortgage rates between -9.1 and -1.2.[34] In a related study, Kung (2015) uses the variation in the conforming loan limit together with the original asking price to asses the likelihood that the change in this limit will affect a property and estimates a value of -6 for this semielasticity. Himmelberg et al. (2005) and Hubbard and Mayer (2009) argue that the user cost model imply a much larger elasticity in absolute value. In fact, in order for the rental rate to remain constant, under plausible values for the key economic parameters of the user cost, they obtain a value for this semielasticity of about -20. But, in my model for the rental rate to remain constant the supply of housing needs to be fixed, that is, the price elasticity of supply needs to equal zero. Taking a zero supply elasticity, equation (9) imply a value close to -20 as estimated by these authors.

Another strand of the literature studies the effect on house prices of the *quantity* of credit supplied. Favara and Imbs (2015) and Di Maggio and Kermani (2015) use regulatory changes to instrument for changes in the supply of credit at the county level and find that the elasticity of house prices to the (instrumented) volume of mortgage loans is between 0.2 and 0.33. Anenberg et al. (2016) construct an instrument for the supply of credit based on a measure of credit availability and estimate an elasticity of 0.9. Using my notation this elasticity at a given metropolitan area j corresponds to $\varepsilon_{p,M,j}$, and it is equal to the ratio of the mortgage rate semielasticity of house prices, $\zeta_{p,r,j}$, to the average mortgage rate semielasticity of mortgage demand, $\zeta_{M,r,j}$. Using the data described above, I can compute this elasticity for each metropolitan area. In line with these

[33] Note that equation (10) approximates the log-difference of house prices, which equals $-15.4/(\varepsilon_{S,p,j}+1)\Delta r \approx -15.4\exp(-\varepsilon_{S,p,j})\Delta r$, suggesting that regressions of (log) house price changes on the interaction of mortgage rate changes and the elasticity of house-price supply can identify the average mortgage-rate semielasticity of mortgage demand (considering a transformation of the price house supply elasticity).

[34] It is interesting to note that the range of estimates provided by Adelino et al. (2014) is about the same as the range of values for the mortgage rate semielasticity of house prices that I estimate. However, these two ranges have different interpretations. Adelino et al. (2014) give a range of estimates for the average semielasticity in 10 MSAs considered in their analysis. In contrast, I provide a range of estimates for 269 MSAs, with the (household-weighted) average of my estimates for the same 10 MSAs in the Adelino et al. (2014)) sample equal to -8.1.

empirical studies, the (house-value-weighted) average of this elasticity is 0.3 (Table 3).

The fact that the average estimated sensitivity of house prices is in line with the empirical studies lends indirect support to my simple framework for welfare analysis and provides external validity to the house price effects used in the welfare calculations described next.

4.3 Estimates of the Welfare Effects of Eliminating MID

In this section, I use the information described in section 3 to measure the distributional impact of mortgage subsidies—its economic incidence—and the efficiency gains from eliminating MID—the negative of the size of the deadweight loss generated by MID.

Incidence. As described in Proposition 3 the elimination of MID will hurt house producers proportionally to the decline in house prices. Estimates by metropolitan area of these price declines were presented in Section 4.2.

Proposition 3 also describes how the elimination of MID will affect households through two channels: increasing mortgage interest payments and reducing house prices. The former hurt all households—homebuyers and homeowners, while the latter hurts homeowners but benefit homebuyers. Table 4 presents my estimates for the incidence of eliminating MID on households' welfare. I consider the incidence measured as a percent of the house value to make these measures comparable across households, the term in parenthesis in equation (11), $-\phi_{p,i}\, p_j/\Delta p_j - \phi_{m,i}\, LTV_i$. Table 4 reports separately for homeowners and homebuyers the average incidence by mortgage term. The first three columns of the table present the estimates of the effect of only higher effective mortgage rates caused by the elimination of MID, assuming no change in house prices. Higher mortgage rates hurt both first-time homebuyers and homeowners, with households using longer mortgage terms being hurt more. Households using longer mortgage terms are hurt more given that increasing the term of the mortgage effectively increases leverage, as captured by the increase in the LTV multiplier (Table 2) and that LTV ratios and mortgage terms are positively related (Table B.2). Comparing the average welfare reduction for the same mortgage term it is observed that eliminating MID will hurt buyers more than owners, reflecting that buyers use higher LTV on average, conditional on mortgage terms (Table B.2). Moreover, on average, buyers are hurt more relative to owners reflecting that my sample of buyers uses relatively longer mortgage contracts.

The last three columns of Table 4 present the estimated incidence on households when both higher effective mortgage rates and lower house prices are taken into account. Lower house prices increase the loss for homeowners. In contrast, lower house prices benefit first-time buyers, who gain from purchasing their first house at a lower price. The effect of house prices is more important in present value the shorter the mortgage term, given my assumption that the house is sold at the end of the mortgage term. All in all, on average, homeowners loss from the elimination of MID corresponds to 11.5% of the value of their house, whereas on average first-time buyers only lose 8.5% of the value of their house. For an average house value of $320,000 these correspond to a loss of $36,800 for homeowners and a loss of $27,200 for homebuyers.

Given the differential response of house prices and heterogeneous mortgage characteristics the incidence is estimated to vary across regions. Figure 4 depicts the average estimated incidence for buyers and owners at a given metropolitan area against the house price supply elasticity in that metropolitan area. Buyers are expected to lose relatively less than owners, who suffer an additional loss from the decline in house prices. This is the case in regions with less elastic supply of housing. But it is the opposite in regions with a more elastic supply, where the difference from the decline in house prices is not enough to offset the larger losses suffered by buyers as they borrow at longer maturities and using higher LTVs (Table B.2).

My estimates display important variation across metropolitan areas for the incidence of the elimination of MID. Figure 5 presents a heat map for the average incidence on first-time buyers by metropolitan area. In the more inelastic coastal regions, the elimination of MID is estimated to cause a larger decline of house prices, thus it is estimated that homebuyers are hurt less in these areas, depicted by the (warmer) lighter pink colors. In contrast, most of the midwest metropolitan areas are depicted in (colder) lighter blue colors, reflecting the higher elasticity of house supply in these regions that translates in an estimated smaller decline in house prices upon the elimination of MID. I estimate that on average homebuyers welfare declines by 12.6% of the house value in Alexandria, Louisiana, whereas homebuyers in San Francisco, where house prices are estimates to drop more, are estimated to lose only 3.8% of the value of the house, representing dollar losses of 40,320 and 12,160 for a 320,000 dollar house, respectively.

Another way to look at the regional variation of the effect of eliminating MID is to onsider average effects at the state level. Figure 6 presents a similar heat map as above considering the average incidence for buyers by state. The same pattern emerges with the coastal and more inelastic states displaying the smallest adverse effect for homebuyers of the elimination of MID, and the interior states displaying the largest adverse effect from the elimination of this subsidy.

For first-time buyers, the benefit from lower house prices can more than offset the loss from higher effective mortgage rate, upon the elimination of MID, as reflected by the positive estimates reported in Table 4 for the maximum of the incidence on first-time buyers. My estimates imply that slightly more than 42,000 first-time buyers, in my sample, would have benefited if MID were not in place. This estimate is likely to understate the number of households that would benefit, as all households are assumed to deduct mortgage interest. Non-itemizing buyers will only benefit from lower house prices.

Efficiency Gains. As described above the efficiency loss generated by MID is proportional to the distortion generated on the (compensated) demand for mortgage debt (equation (12)). Table 5 presents the contribution of the change in house prices and effective mortgage rates to the change in this demand. The elimination of MID, on average, will increase effective mortgage rates by about one percentage point. This increase in effective mortgage rates is estimated to *directly* reduce the demand for mortgage debt by 15.7% of the (current) house value. Moreover, the increase in effective mortgage rates *indirectly* increase the demand for mortgage debt by 5.8% of the (current) house value, as higher effective mortgage rates lower house prices. In fact, I estimate that the elimination of MID causes a decline in house prices of 5.7%, on average over households, when the compensated responses of house demand are considered.[35] Table 5 presents the total distortion in the demand for mortgage debt as a percent of the house value. All in all, on average, the elimination of MID is estimated to reduce mortgage demand by 9.9%. The upshot is that the demand for mortgage debt responds about 40% less due to the offset coming from the decline in house prices. In other words, abstracting from the offseting effect of house prices, as in Poterba (1992), would yield larger efficiency cost estimates for MID and other mortgage subsidies.[36]

Table 6 presents descriptive statistics for the efficiency costs for first-time buyers and home-owners by mortgage term. The first three columns present estimates of the efficiency loss as basis points of the house value. The elimination of MID is estimated to create average efficiency gains of 5.1 basis points of house values. By the Harberger triangle formula, the estimated efficiency gain is one-half of the product of the change in the (compensated) demand for mortgage debt and the size of the current mortgage subsidy. The former estimated to be 9.9% of the house value and the latter estimated to be roughly 100 basis points. These values imply an average efficiency gain of about 5 basis points of the house value. The last three columns of Table 6 present the estimated average dollar value of the efficiency losses from eliminating MID (negative values correspond to efficiency gains). The average efficiency gain is about $150 dollars per household, ranging from gains of $82,600 to losses of $10. Households who increase their (compensated) demand for mortgage debt in response to the elimination of MID contribute to efficiency losses. This is the case for households who are currently borrowing at very low mortgage rates so the effective increase in mortgage rates from eliminating MID is small in percentage points and for whom the effect

[35]The estimated price decline is lower when the income compensations are taken into account—compare 5.7% decline with a household-weighted average decline in house prices of 6.3% for the estimates reported in section 4.2. From the Slutzky equations we have that the compensated elasticities of house demand with respect to mortgage rates and house prices are less elastic than their uncompensated analogues. On the one hand, a less elastic mortgage rate semielasticity imply that house demand respond less to the same increase in effective mortgage rates. On the other hand, a less elastic price elasticity imply that house prices need to adjust more to re-equilibrate the housing market after a given increase in house demand. My estimates imply that the former effect dominates and house prices drop less when income compensations are accounted for.

[36]My estimates for the efficiency costs of MID are not readily comparable to Poterba (1992), as that study considers a different sample period when interest rates were materially larger than in my sample, and as it approximates the distortion in compensated mortgage demand by the change in compensated housing demand, instead of expressing the distortion of the compensated mortgage demand by the sufficient statistics that describe house demand using the Slutzky equations and budget constraints.

of lower house prices determines the direction of the response of mortgage debt. Total efficiency gains, for my sample of 17.6 million mortgages, add up to $2.6 billion.

Assuming my sample is a random subsample of the 49 million households that finance their house with mortgage debt (U.S. Census Bureau 2010-2014), an upper bound for the total efficiency gains from the elimination of MID would be a modest $7.3 billion.

5 Conclusion

In this paper, I argue that the welfare evaluation of interest rate subsidies needs to account for *both* the effects on the effective interest rate and the price of the asset financed with the subsidized debt. But, to the best of my knowledge, the welfare evaluation of debt subsidies using a sufficient statistics approach has not accounted for the effect on asset prices, in general, or house prices, in the case of mortgage subsidies.

In the first part of this paper, I generalize the classic sufficient statistic formulas to measure the welfare effect of mortgage subsidies considering the effect of house prices. This characterization yields novel insights. First, imperfect financial markets increase information requirements for the welfare evaluation of debt policies, as the LTV ratio, or balance sheet information more broadly, becomes an additional sufficient statistic to measure the incidence of the policy. Second, the adjustment of house prices overturns the classic result that subsidies always (weakly) benefit their recipients. Indeed, linear mortgage subsidies act as nonlinear subsidies on total house financing and may hurt first-time homebuyers. Finally, the response of house prices attenuates the efficiency cost of mortgage subsidies, because higher house prices attenuate the distortions in the (compensated) mortgage demand.

In the second half of the paper, I use my generalized sufficient statistics formulas to gauge the effects of eliminating mortgage interest deduction (MID) across 269 metropolitan areas in the U.S. One empirical challenge to perform these calculations is obtaining cleanly identified estimates of the elasticity of housing demand with respect to the mortgage rate, as any change in mortgage rates is expected to influence house prices as well. I overcome this challenge, by showing that the aforementioned elasticity equals the ratio of the price house demand elasticity and the user cost at the household level (Lemma 1). I use this relationship to estimate individual mortgage-rate house demand elasticities, based on information on individual user costs and available estimates of the price house demand elasticity.

Using my estimates of the mortgage-rate house demand elasticity, information from a sample of 17.6 million mortgages, and other estimates from the literature, I provide new estimates of the effect of eliminating MID that vary across households and metropolitan areas. First, I estimate that the elimination of MID will lead to house price declines between 1.2 and 9.6 percent, depending on the local price house supply elasticity. Second, homebuyers stand to loose relatively less than homeowners from this policy change (8.5 versus 11.5 of the house value), as homeowners are hurt both by the higher effective mortgage rates and the lower house prices. Importantly, welfare effects vary considerably across households depending on both the characteristics of the mortgage contract being used (term, rate, and LTV) and the local response of house prices. Finally, efficiency gains are estimated to amount to a modest $7.3 billion, extrapolating from my sample to all households that purchase their house with mortgage debt, reflecting the attenuating effect of house prices. My estimates suggest that this attenuation mechanism reduces the efficiency gains from the elimination of MID by about 40%.

Future work should investigate how the results of the applied framework for welfare analysis presented in this paper are influenced by the adjustment along the extensive margin of house demand, which my analysis abstracted away from. The adjustment along the extensive margin of housing demand, i.e., between renting and owning, may change the welfare effects of mortgage subsidies. However, previous research suggests that the adjustment along the extensive margin is small in response to mortgage subsidies, precisely because of the response in house prices (Glaeser and Shapiro 2003, Bourassa and Yin 2008, Hilber and Turner 2014, Sommer and Sullivan 2016).

Future work can use the techniques and insights developed in this paper to measure the welfare effect of debt policies in other settings, like the deductibility of corporate interest or the subsidies to student debt. In these cases, the evaluation of debt policies ought to consider the spillovers of debt policies into the market for debt-financed assets: structures and equipment or college tuition.

My new insights and evidence regarding the effect of mortgage subsidies help to inform the public debate about the desirability of mortgage subsidies and the design of housing policy. If the government were to maintain tax subsidies to encourage home ownership and the progressivity of the tax code, my analysis suggests that a preferred alternative would be to have a *fixed* tax credit for homebuyers. This tax credit could be designed to span the duration of the house investment, in the same way that an interest deduction spans the duration of the mortgage.[37] Furthermore, it would act as a lump sum subsidy, limiting the distortions introduced by the policy. In fact, it should only distort the owning-versus-renting decision. Moreover, a fixed tax credit will be progressive, as it will represent a larger fraction of house expenditure for lower income households.

[37] In fact, one can consider that the households take an hypothetical mortgage, with fixed monthly payments, in order to calculate the desired tax credit that will be granted for the remaining balance on that hypothetical mortgage each year.

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Appendix

A Proofs

Proof of Proposition 1: Let $V(t) = V(p(t), r(t), y)$ denote households' indirect utility function. From the utility maximization of households the indirect utility function is given by

$$V(t) = u(x, c) - u_c(1 + r(t))[px - y - (q + t)m] - u_c[c - (1 - \delta + \pi)px + m] \ ,$$

where I have substituted for the lagrange multipliers in an interior solution of the households' problem. Applying the Envelope Theorem I get

$$\begin{aligned} \frac{dV}{dt} &= -u_c \frac{dr(t)}{dt}[px - y - (q + t)m] - u_c(1 + r(t)) \left[\frac{dp(t)}{dt} x - \left(\frac{dq(t)}{dt} + 1 \right) m \right] + u_c(1 - \delta + \pi) \frac{dp(t)}{dt} x \\ &= u_c px \left(-\frac{1}{p} \frac{dp(t)}{dt} [r(t) + \delta - \pi] + (1 + r(t))^2 LTV \right) \ , \end{aligned}$$

where I used that $dq/dt = 0$ if $r = r_f + \rho$, $px - y - (q+t)m = 0$, $1 + r(t) = 1/(q+t)$, and $LTV = (q+t)m/(px)$. Moreover, since $dr/dt = -(1 + r(t))^2$, applying the Chain Rule I get

$$\frac{dV}{dt} = u_c px(1 + r(t))^2 \left(\frac{1}{p} \frac{\partial p}{\partial r} [r(t) + \delta - \pi] + LTV \right)$$

Since homeowners sell all their endowment of housing, the incidence on them equals $-(1+r(t))^2 h \, \partial p/\partial r$. Similarly, applying the Envelope Theorem to the profit maximization of house producers, I get that the incidence on these agents equals $-(1 + r(t))^2 z \, \partial p/\partial r$.

On the other hand, implicit differentiation of equation (2) yields

$$\frac{dS(p)}{dp} \frac{dp(t)}{dt} = \frac{\partial D(p(t), r(t))}{\partial p} \frac{dp(t)}{dt} + \frac{\partial D(p(t), r(t))}{\partial r} \frac{dr(t)}{dt} \ .$$

By the Chain Rule $(\partial p/\partial r)(dr/dt) = dp/dt$. Substituting for dp/dt in the expression above, multiplying by p/D, and rearranging I get

$$\frac{1}{p} \frac{\partial p}{\partial r} = \zeta_{p,r} = \frac{\zeta_{D,p}}{\varepsilon_{S,p} - \varepsilon_{D,p}} < 0$$ ■

Proof of Proposition 2: By definition the excess burden of a mortgage subsidy t is given by

$$EB(t) = e(p(t), r(t), v) - \pi(t) - e(p(0), r_M(0), v) + \pi(0) - (p(t) - p(0))h + G(p(t), r(t), t, e(p(t), r(t), v)) \ .$$

In order to approximate the excess burden with a second order Taylor polynomial, I calculate the following derivatives. First, using the Envelope Theorem in the households' expenditure minimization problem together with a fix mortgage interest rate (price) and house price in period 1 I get

$$\frac{de(t)}{dt} = \frac{dp(t)}{dt} x - m \ ,$$

where the derivative of the multiplier of the period-1-flow-budget constraint canceled given that that constraint is active. Second, using the Envelope Theorem in the producers' maximization problem I get $d\pi(t)/dt = z\; dp(t)/dt$, and noting that homeowners sell all their endowment independent of prices, $d(p(t)h)/dt = h\, dp(t)/dt$. Finally, taking derivatives of the government subsidy expenditure, I get

$$\frac{dG(p(t), r(t), t, y)}{dt} = m(p(t), r(t), y) + t\,\frac{dm(p(t), r(t), y)}{dt}\ .$$

Therefore,

$$\frac{dEB(t)}{dt} = t\,\frac{dm(p(t), r(t), y)}{dt}\ ,$$

where I used that $x = z + h$ in equilibrium.

Taking second derivatives,

$$\frac{d^2EB(t)}{dt^2} = \frac{dm(p(t), r(t), y)}{dt} + t\,\frac{d^2m(p(t), r(t), y)}{dt^2}\ .$$

Ignoring the curvature terms and using a second order Taylor approximation, I get

$$EB(t) \approx \frac{dEB(0)}{dt}\,t + \frac{1}{2}\frac{d^2EB(0)}{dt^2}\,t^2 = \frac{1}{2}\frac{dm(p(0), r(0), y)}{dt}\,t^2 = \frac{1}{2}\Delta m\, t\ ,$$

where I used that $dm/dt\,\Delta t = \Delta m$, with $\Delta t = t - 0$ and $\Delta m = m(t) - m(0)$. On the other hand, from the household budget constraint $m(p(t), r(t), y) = p(t)x(p(t), r(t), y) - y - T$ so

$$EB(t) \approx \frac{1}{2}\frac{dm}{dt}\,t^2 = -\frac{1}{2}(1 + r(t))^2 px\left(\zeta_{p,r} + \zeta_{D,r} + \varepsilon_{D,p}\zeta_{p,r}\right)t^2 \qquad \blacksquare$$

Proof of Proposition 3:

Let a tilde denote the monthly counterpart of variables. That is, let $\tilde{T}_i = 12T_i$, let $\tilde{r}_i(\varphi)$ be the monthly mortgage rate with $(1 + \tilde{r}_i(\varphi))^{12} = 1 + r_i(\varphi)$, and so on. Then, I can write the problem of a first-time buyer as

$$\begin{aligned}
&\max u(x_i, c_{i0}, \ldots, c_{i\tilde{T}_i})\\
\text{s.t.}\qquad & p_{j0}x_i + c_{i0} + T_0 \le y_{i0} + m_{i0}\\
& c_{i1} + (1 + \tilde{r}_i(\varphi))m_{i0} + T_1 \le y_{i1} + m_{i1}\\
&\vdots\\
& c_{i\tilde{T}_i} + (1 + \tilde{r}_i(\varphi))m_{i,\tilde{T}_i-1} + T_{\tilde{T}_i} \le y_{i\tilde{T}_i} + p_{j\tilde{T}_i}(1 - \tilde{\delta} + \tilde{\pi})^{\tilde{T}_i}x_i
\end{aligned}$$

Let λ_t be the Lagrange multiplier of the budget constraint in period t, then from the FOC with respect to mortgage debt it follows that $\lambda_t = \lambda_{t+1}(1 + \tilde{r}_i(\varphi))$. From where it follows that

$$\lambda_t = (1 + \tilde{r}_i(\varphi))^{-t}\lambda_0\ . \tag{A.1}$$

On the other hand, the Envelope Theorem imply that

$$\frac{dV_i(\varphi)}{d\varphi} = -\lambda_0 \frac{dp_{j0}(\varphi)}{d\varphi} x_i - \sum_{t=1}^{\tilde{T}_i} \lambda_t m_{i,t-1} \frac{d\tilde{r}_i(\varphi)}{d\varphi} + \lambda_{\tilde{T}_i} (1 - \tilde{\delta} + \tilde{\pi})^{\tilde{T}_i} \frac{dp_{j\tilde{T}_i}(\varphi)}{d\varphi} x_i \ .$$

In addition, by assumption a permanent increase in φ imply that $dp_{j0}/d\varphi = dp_{j\tilde{T}_i}/d\varphi \equiv dp_j/d\varphi$. This relationship together with equation (A.1) and that the mortgage unpaid balance m_{it} for a fixed mortgage with monthly payment a and term $\tilde{T}_i$ is given by

$$m_{it} = \frac{a}{\tilde{r}_i(\varphi)} \left(1 - \frac{1}{(1 + \tilde{r}_i(\varphi))^{\tilde{T}_i - t}}\right) ,$$

allow me to rewrite the incidence as

$$\frac{dV_i(\varphi)}{d\varphi} = -\lambda_0 \left[1 - \frac{(1 - \tilde{\delta} + \tilde{\pi})^{\tilde{T}_i}}{(1 + \tilde{r}_i(\varphi))^{\tilde{T}_i}}\right] \frac{dp_j(\varphi)}{d\varphi} x_i$$
$$- \lambda_0 m_{i0} \left[\frac{1}{(1 + r_i(\varphi))^{\frac{1}{12}} - 1} - \frac{12T_i}{(1 + r_i(\varphi))^{\frac{1}{12}} \left[(1 + r_i(\varphi))^{T_i} - 1\right]}\right] \frac{d\tilde{r}_i(\varphi)}{d\varphi} \ .$$

Using that $(1 - \tilde{\delta} + \tilde{\pi})^{\tilde{T}_i} / (1 + \tilde{r}_i(\varphi))^{\tilde{T}_i} \approx (1 - r_i(\varphi) - \delta + \pi)^{T_i}$ and that $d\tilde{r}_i(\varphi)/d\varphi = -\tau_y i_i$, I obtain equation (11).

On the other hand, for homeowners everything is the same except for the period 0 budget constraint, which will be given by

$$p_{j0} x_i + c_{i0} + T_0 \leq y_{i0} + m_{i0} + p_{j0} h_i \ ,$$

where h_i is the house endowment of homeowners. By assumption $x_i = h_i$ so the term representing the effect of house prices in period 0 cancels and I obtain equation (11). ■

B Description of Mortgage Level Data

The data corresponds to McDash Analytics (formerly LPS) and Equifax Credit Risk Insight Servicing (CRISM). The former is used to obtain information on mortgage characteristics (term, house value, property zip code, LTV ratio, mortgage rate, lien on the property, and mortgage type), whereas the latter is used to identify first-time home buyers.

I consider mortgages originated in 2010-2015, focusing on first-lien mortgages with LTV no greater than 150%, fixed rates, and terms of 10, 15, 20, 25, and 30 years. These mortgages are by far the most commonly used and represent more than 90% of the mortgages originated in 2010-2015 (Table B.1). Table B.2 presents descriptive statistics for the nominal mortgage rate and LTV ratio for the the mortgages in my final sample.

To identify first time home buyers I use CRISM, which matches credit bureau data with mortgage information. Equifax uses a proprietary and confidential algorithm to match mortgage data from McDash/LPS using anonymous characteristics and payment histories. Each credit history is matched with a single borrower in the LPS data, including first, second, and refinance mortgages. Information is included for the life of the mortgage, six months preceding origination, and six months following termination.

Based on more than twenty variables LPS and Equifax records are matched and assigned a match score from 0 (no match) to 0.9 (close to perfect match). I restrict the sample to match scores of 0.8 and above, which according to Equifax corresponds to roughly 90% of mortgages. The data has a one year lag to

Table B.1: Mortgages Originated in 2010-2015 in LPS.

Description	Observations (millions)
Mortgages originated in 2010-2015	26.8
LTV > 150%	0.7
Non-fixed rate mortgages	1.6
Terms other than 10, 15, 20, 25, and 30	0.3
Second-lien mortgages	0.02
Fixed rate mortgages 10, 15, 20, 25, and 30 years	24.2
Lost in merge with CRISM	0.07
In zip codes with elasticity information	19.5
Without interest rate information	0.2
Non-owners	1.7
Final sample	17.6

Source: McDash Analytics and Equifax Credit Risk Insight Servicing.

Table B.2: Mortgage Rate and LTV for Buyers and Owners by Mortgage Term.

Term (years)	Number of Mortgages	Interest Rate (percent) Mean	Interest Rate (percent) Min	Interest Rate (percent) Max	LTV Ratio (percent) Mean	LTV Ratio (percent) Min	LTV Ratio (percent) Max
Owners	14,331,587	4.13	1.00	18.00	74.3	0.0	150.0
10	541,909	3.59	1.00	18.00	46.9	0.2	150.0
15	3,035,368	3.66	1.00	13.38	63.7	0.0	150.0
20	930,503	4.18	1.50	13.55	71.2	0.6	150.0
25	144,844	4.41	2.00	12.19	79.9	0.4	150.0
30	9,678,963	4.29	1.00	18.00	79.4	0.0	150.0
Buyers	3,263,089	4.31	0.00	11.12	89.8	0.0	150.0
10	6,049	3.56	1.00	10.28	53.0	0.5	107.0
15	120,640	3.60	1.88	11.12	73.2	0.0	117.5
20	12,786	4.18	2.52	10.87	74.1	0.7	125.4
25	1,655	4.38	2.56	6.13	85.0	22.2	108.9
30	3,121,959	4.34	0.00	10.99	90.6	0.0	150.0
All	17,594,676	4.16	0.00	18.00	77.2	0.0	150.00

Notes: Author's calculations based on McDash Analytics and Equifax Credit Risk Insight Servicing.

ensure all the information to perform the match is present and avoid false positives, so I restrict the sample to 2010:1-2015:4.

First time home buyers are identified using two filters. The first filter is that the mortgage purpose is a purchase, as specified by variable 'purpose_type' in LPS. The second filter, using data from CRISM, is that neither the primary nor the secondary borrower associated to the mortgage record ('loan_id') has a mortgage open or a history of a previous mortgage over the six months previous to origination. This filter considers whether any of the following mortgage accounts was previously open: largest first mortgage ('fm_lrg_opendt'), second largest first mortgage ('fm_2lrg_opendt'), largest closed-end second ('ces_lrg_opendt'), second largest closed-end second ('ces_2lrg_opendt'), largest home equity line of credit ('heloc_lrg_opendt'), and second largest home equity line of credit ('heloc_2lrg_opendt'). These filters identify 3.2 million first-time buyers in my sample, representing an 18.5 percent of all mortgages. Table B.2 presents descriptive statistics for the nominal mortgage rate and LTV ratio by mortgage term for first-time buyers and homeowners, separately. First-time buyers borrow using longer mortgage terms and use higher LTV ratios, accordingly, on average they pay higher mortgage rates.

Mortgages from LPS are assigned to MSA/NECMA divisions using ZIP codes. I map ZIP codes to counties in these divisions assuming that a ZIP code belongs to a county when the ratio of residential addresses in that county to the total number of residential addresses in the ZIP code is at least 50%. Since Saiz (2010) elasticities are for MSA/NECMA divisions using 1999 codes, I consider the county composition for these regions in 1999.

Tables and Figures

Table 1: Descriptive Statistics of Borrower-level Characteristics.

Description	Mean	Std.Dev.	Min	Max
Nominal mortgage rate, i_i (percent)	4.16	0.63	0.001	18.00
Effective mortgage rate, $r_i - \tau_y i_i$ (percent)	1.12	0.47	-2.00	11.50
Real user cost (percent)	4.9	0.5	1.8	15.3
Mortgage-rate demand semielasticity, $\zeta_{D,r,i}$	-15.3	1.5	-41.1	-4.9
LTV ratio (percent)	77.2	21.3	0.0	150.0
Mortgage term, T_i (years)	26.1	6.6	10.0	30.0
House value (dollars)	319,351	316,837	1,307	100,000,000
First-time buyer indicator	0.185	0.389	0.000	1.000

Notes: Author's calculations based on McDash Analytics and Equifax Credit Risk Insight Servicing.

Table 2: Price and LTV Multipliers for Buyers and Owners by Mortgage Term.

Term	Price Multiplier			LTV Multiplier		
(years)	Mean	Min	Max	Mean	Min	Max
Owners	-0.30	-0.77	-0.01	11.9	3.7	16.2
10	-0.63	-0.77	-0.19	5.0	3.7	5.2
15	-0.50	-0.68	-0.15	7.3	5.7	7.9
20	-0.36	-0.55	-0.08	9.6	7.0	10.4
25	-0.27	-0.43	-0.05	11.7	8.5	12.9
30	-0.21	-0.46	-0.01	14.0	7.2	16.2
Buyers	0.78	0.23	0.96	13.7	4.3	16.9
10	0.37	0.23	0.63	5.0	4.3	5.2
15	0.50	0.39	0.80	7.4	6.0	7.7
20	0.64	0.53	0.88	9.6	7.6	10.1
25	0.73	0.61	0.81	11.7	10.9	12.6
30	0.79	0.42	0.96	13.9	10.1	16.9
All	-0.10	-0.77	0.96	12.2	3.7	16.9

Notes: Price and LTV multipliers corresponds to the coefficients that multiply the price effects and the mortgage rate effect (LTV) in the expression for the incidence on first-time buyers and homeowerns in Proposition 3.
Author's calculations based on McDash Analytics and Equifax Credit Risk Insight Servicing.

Table 3: Descriptive Statistics of Key Economic Parameters and Effect of Mortgage Subsidies by MSA.

Description	Mean[(1)]	Std.Dev.[(1)]	Min	Max
Price house supply elasticity, $\varepsilon_{S,p,j}$ (Saiz, 2010)	1.49	0.90	0.60	12.15
Mortgage rate house demand semielasticity, $\zeta_{D,r,j}$	-15.4	0.1	-16.1	-15.1
Value of the housing stock (millions)	128,105	117,780	226	405,673
Mortgage rate price semielasticity, $\zeta_{p,r,j}$	-6.85	1.94	-9.60	-1.18
House price change elimination MID, $\Delta p_j/p_j$ (percent)	-6.93	1.97	-9.83	-1.18
Comp. price change elimination MID, $\Delta \hat{p}_j/p_j$ (percent)	-6.33	2.04	-9.24	-0.96
Credit house price elasticity, $\varepsilon_{p,M,j}$	0.30	0.07	0.06	0.44
Average incidence (percent of house value)	-10.3	0.7	-12.0	-8.6
Total dollar value of incidence to households (millions)	-12,834	11,569	-39,358	-24
Average efficiency loss (basis points of house value)	-4.6	1.0	-7.3	-3.2
Total dollar value of efficiency loss (millions)	-52.1	44.3	-162.0	-0.1

Notes: [(1)]Total metropolitan area house-value-weighted mean and standard deviations.
Author's calculations based on McDash Analytics, Equifax Credit Risk Insight Servicing and Saiz (2010).

Table 4: Incidence of Mortgage Subsidies for Buyers and Owners by Mortgage Term.

Term	Incidence of higher mortgage rates (percent of house value)			Total Incidence (percent of house value)		
(years)	Mean	Min	Max	Mean	Min	Max
Owners	-9.6	-36.2	0.0	-11.5	-36.4	-0.3
10	-2.1	-10.5	0.0	-6.0	-13.1	-1.1
15	-4.3	-20.0	0.0	-7.3	-21.3	-1.1
20	-7.1	-23.9	-0.1	-9.4	-24.9	-1.7
25	-10.2	-28.9	-0.1	-11.9	-29.4	-1.0
30	-11.9	-36.2	0.0	-13.3	-36.4	-0.3
Buyers	-13.3	-27.2	0.0	-8.5	-23.6	8.2
10	-2.3	-8.9	0.0	-0.1	-6.2	4.0
15	-4.8	-12.4	0.0	-1.9	-9.1	6.5
20	-7.4	-16.0	-0.1	-3.5	-12.1	4.8
25	-10.9	-16.8	-2.6	-6.6	-13.9	3.6
30	-13.7	-27.2	0.0	-8.8	-23.6	8.2
All	-10.2	-36.2	0.0	-10.9	-36.4	8.2

Notes: Total incidence considers both house price effects and lower mortgage rates. See Proposition 3 for details.
Author's calculations based on McDash Analytics, Equifax Credit Risk Insight Servicing and Saiz (2010).

Table 5: Compensated Mortgage Demand Distortions of Mortgage Subsidies for Buyers and Owners by Mortgage Term.

Term (years)	House price effect (percent of house value) Mean	Min	Max	Mortgage rate effect (percent house value) Mean	Min	Max	Total effect (percent house value) Mean	Min	Max
Owners	5.8	1.0	9.9	-15.7	-22.5	-7.3	-9.8	-19.0	1.9
10	5.6	1.0	9.8	-14.8	-22.3	-7.3	-9.2	-18.8	-1.8
15	5.6	1.0	9.9	-14.9	-21.2	-7.3	-9.4	-19.0	-1.3
20	5.7	1.0	9.7	-15.8	-21.4	-9.5	-10.1	-18.3	-3.5
25	5.7	1.0	9.8	-16.0	-21.0	-11.3	-10.3	-18.4	-4.3
30	5.9	1.0	9.9	-15.9	-22.5	-7.3	-10.0	-18.9	1.9
Buyers	5.6	1.0	9.7	-15.9	-20.6	0.0	-10.3	-17.1	3.4
10	5.4	1.0	9.5	-14.7	-20.3	-7.3	-9.3	-16.5	-2.4
15	5.3	1.0	9.7	-14.8	-20.5	-10.9	-9.5	-17.0	-2.1
20	5.4	1.0	9.4	-15.7	-20.5	-12.7	-10.3	-16.2	-4.5
25	5.3	1.0	9.4	-16.0	-17.9	-12.8	-10.7	-15.5	-5.4
30	5.6	1.0	9.7	-16.0	-20.6	0.0	-10.4	-17.1	3.4
All	5.8	1.0	9.9	-15.7	-22.5	0.0	-9.9	-19.0	3.4

Notes: See equation (13) for details. Author's calculations based on McDash Analytics, Equifax Credit Risk Insight Servicing and Saiz (2010).

Table 6: Efficiency Loss from Mortgage Subsidies for Buyers and Owners by Mortgage Term.

Term (years)	Basis points of house value Mean	Min	Max	Dollar value Mean	Min	Max
Owners	-5.0	-32.6	0.2	-146	-75,790	13
10	-4.1	-32.6	-0.2	-116	-3,404	0
15	-4.2	-24.1	-0.2	-123	-39,175	-1
20	-5.1	-25.0	-1.1	-132	-7,800	-6
25	-5.5	-22.6	-1.1	-139	-36,727	-7
30	-5.2	-30.9	0.2	-157	-75,790	13
Buyers	-5.4	-20.3	0.2	-103	-78,053	12
10	-4.1	-18.5	-0.4	-86	-1,245	-1
15	-4.2	-20.3	-0.5	-97	-41,317	-4
20	-5.3	-19.1	-1.7	-116	-13,597	-5
25	-5.7	-10.7	-1.9	-94	-740	-10
30	-5.5	-20.3	0.2	-103	-78,053	12
All	-5.1	-32.6	0.2	-148	-82,599	10

Notes: See equation (12) for details.
Author's calculations based on McDash Analytics, Equifax Credit Risk Insight Servicing and Saiz (2010).

Figure 1: Incidence of Subsidy in Mortgage and Housing Markets.

(a) Mortgage Market (b) Housing Market

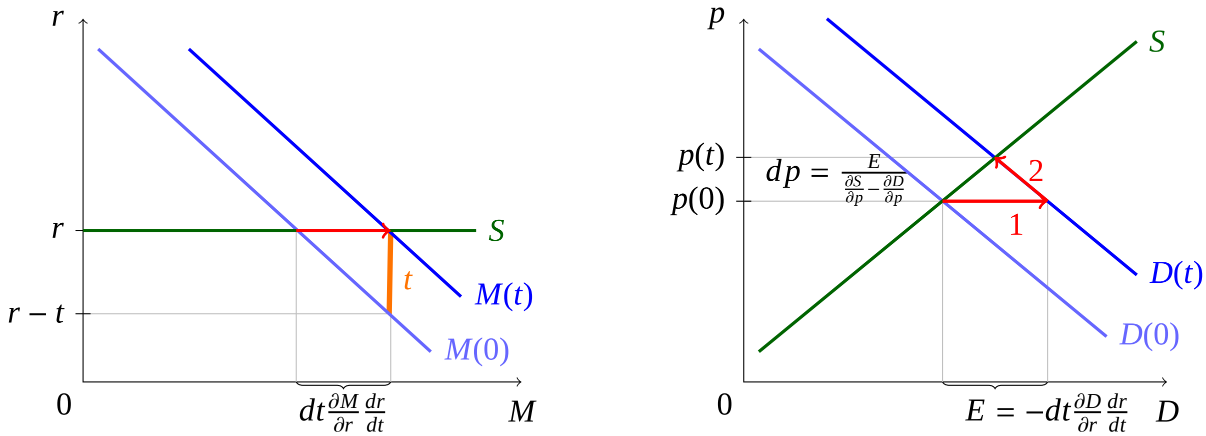


Figure 2: Efficiency Cost of Mortgage Subsidies in Mortgage and Housing Markets.

(a) Mortgage Market (b) Housing Market

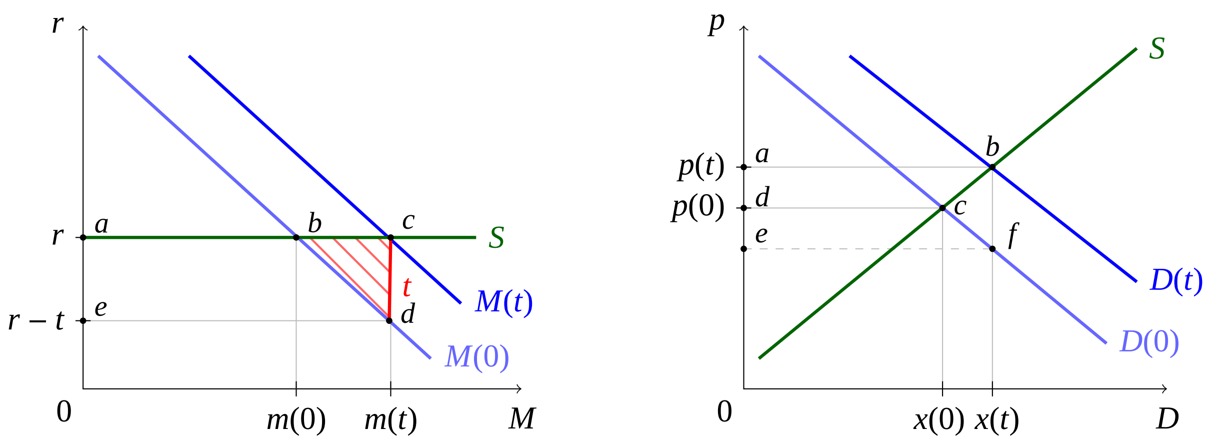
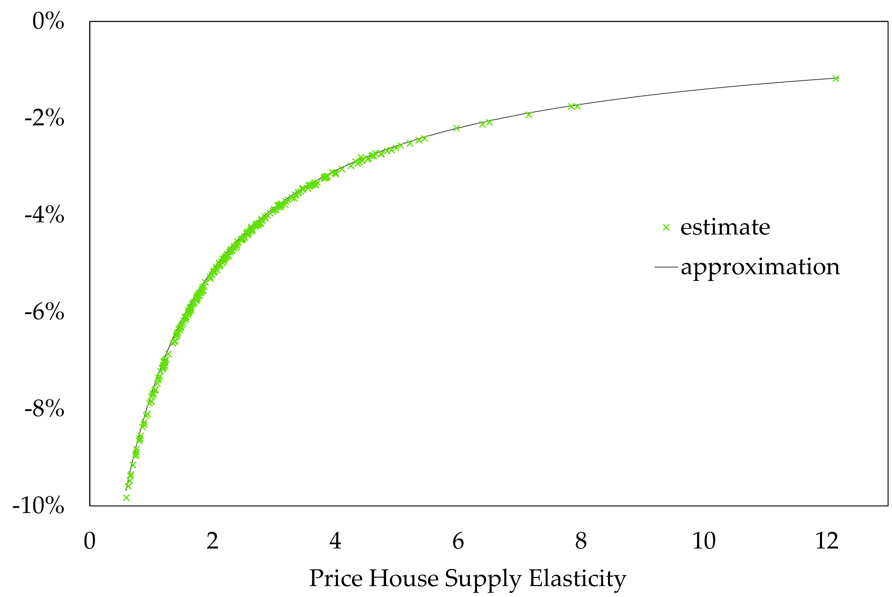


Figure 3: House Price Effect of Eliminating MID by Metropolitan Area.

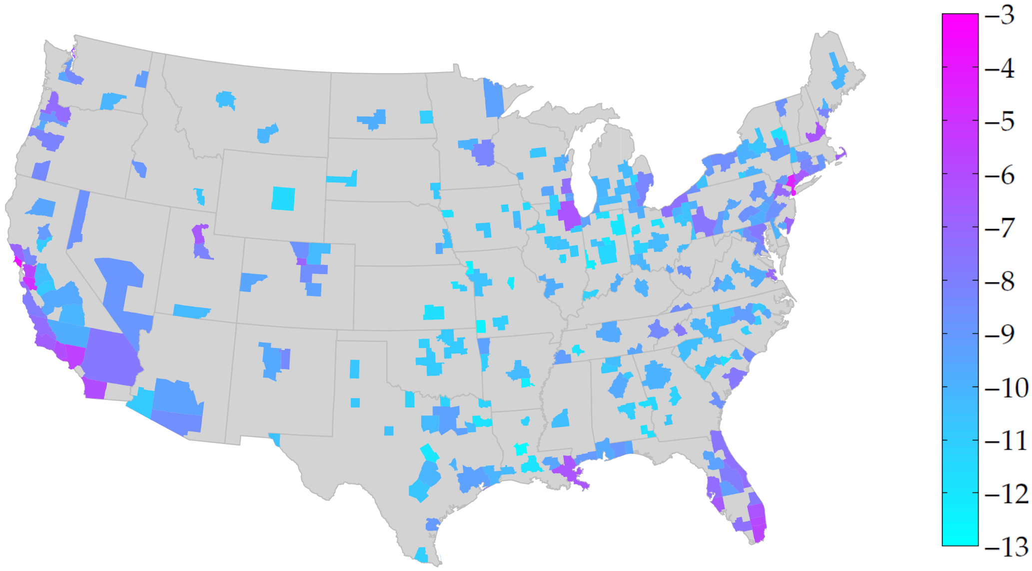


Notes: Estimates corresponds to the estimated values using equation (10). The approximation corresponds to $-15.4/(\varepsilon_{S,p,j}+1)$, where $\varepsilon_{S,p,j}$ is the house price supply elasticity.
Author's calculations based on McDash Analytics and Saiz (2010).

Figure 4: Average Incidence from the Elimination of MID and Price House-Supply Elasticity.

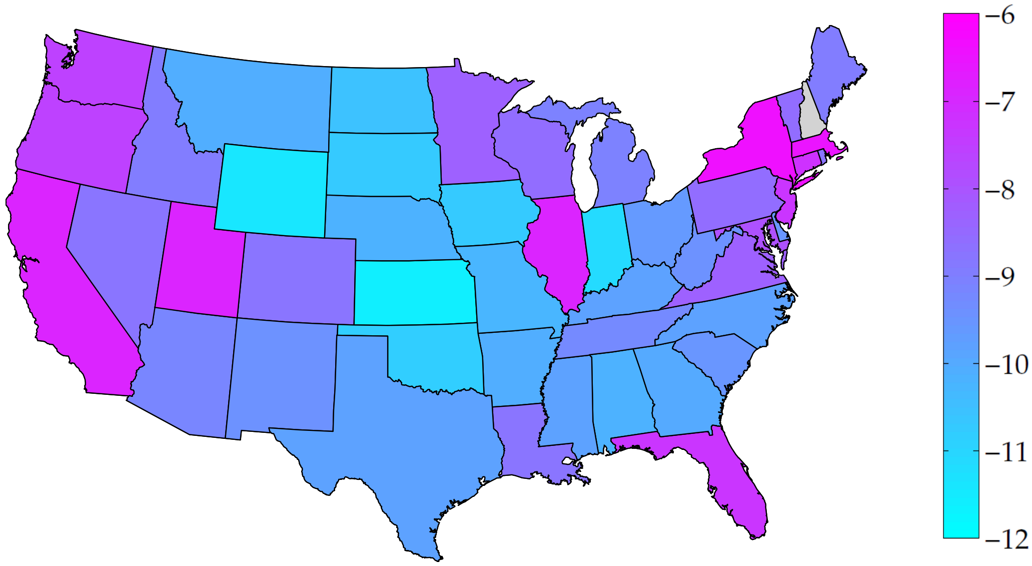
Notes: Incidence estimates measured as percent of house value, $-\phi_{p,i}\, p_j/\Delta p_j - \phi_{m,i}\, LTV_i$, equation (11).
Author's calculations based on McDash Analytics, Equifax Credit Risk Insight Servicing, and Saiz (2010).

Figure 5: Average Incidence for First-Time Buyers of Eliminating MID by MSA



Notes: Welfare is measured in percent of house value.
Author's calculations based on McDash Analytics, Equifax Credit Risk Insight Servicing, and Saiz (2010).

Figure 6: Average Incidence for First-Time Buyers of Eliminating MID by State



Notes: Welfare is measured in percent of house value.
Author's calculations based on McDash Analytics, Equifax Credit Risk Insight Servicing, and Saiz (2010).