Subsidies and Housing Market Equilibrium: Evidence from Colombia

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November 7, 2021

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Abstract

To provide affordable housing, many governments rely on the private sector and subsidies to developers or households. I study the effect of downpayment subsidies, subsidized interest rates, and tax refunds for developers on the housing market in Colombia. I use an arbitrary cutoff defining subsidy eligibility and generating discontinuous incentives for households and developers to bunch. Using administrative and census data, I show evidence of bunching at the cutoff. The subsidy doubled during the study period, and, as a result, the share of units sold at the price cutoff increased from 1 to 7 percent of the market share. Households and developers buy and produce housing units up to 30 percent smaller to benefit from the policy. To explain the observed equilibrium and motivate an identification strategy to recover the model primitives, I propose a housing market equilibrium model that allows product differentiation and heterogeneous developers and households. I find that housing and consumption of other goods are gross complements with an elasticity of substitution of 0.9. The marginally subsidized households increased their utility in about the same magnitude throughout my study period despite the increase in the subsidy amount. Without the tax refund, developers may exit the market; their profits would be 14 percent lower.

*I am grateful to Andrew Foster, Jesse Shapiro, Matthew Turner and Kenneth Chay for their constant support. I am also thankful to Daniel Bjorkegren, Bryce Steignberg, John Friedman, Nick Reynolds, Stefan Hut, Ryan Kessler and seminar participants at Brown University. The Ministry of Housing and CAMACOL facilitating access to the data, I want to thank Santiago Guerrero, Adriana Zambrano, Alan Asprilla and Edwin Chirivi for providing useful information and for their help.
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I. Introduction

Governments around the world adopt housing policies to avoid a housing affordability crisis and to satisfy the urban housing demand caused by rapid urbanization. These policies can take the form of direct government interventions, building social housing, or governments can rely on the private sector and provide subsidies to developers or households. In the '90s, many countries stopped building public housing in favor of subsidies for owner-occupied housing built by private developers.[1] How does the housing market equilibrium respond to these incentives? Do households and developers benefit from them?

A fundamental difficulty in addressing these questions is that incidence evaluations of such policies need an accurate housing market equilibrium model and credible empirical estimates. Housing market elasticities are scarce because of data limitations and lack of valid quasi-experimental variation.[2] Modelling housing markets is challenging because it is a differentiated product traded in a market with heterogeneous households and developers. Including these features is important, however, because the policy and incidence evaluation differs from the standard economic framework of perfectly competitive markets with homogeneous goods and agents.

This paper overcomes these challenges by studying the Colombian housing policy approach. In Colombia, low-income households can receive a cash transfer for the downpayment of a mortgage, and a subsidized interest rate to buy a new low-cost housing unit.[3] Developers who build low-cost housing receive a tax incentive from the government. A housing unit classifies as low-cost if its price is below 135 times the monthly minimum wage (mMW) roughly 40,000 USD. The arbitrary cutoff introduces nonlinear incentives for both developers and households to bunch at the price threshold.

I propose an economic model with heterogeneous buyers and sellers of a vertically

[1]For example, the World Bank among others promoted and approach based on savings, subsidized bonds and credit to promote home-ownership and new construction. This approach was implemented in many Latin American including Chile, Brasil and Colombia and it is called *ABC* for savings, bonds credit in Spanish. For more details and a discussion about Latin American Housing Policy see A. Gilbert (2014) or Cohen, Carrizosa, and Gutman (2019). This approach is similar to *help to buy* in the UK or some first time buyers programs in the USA.

[2]For papers using quasi-experimental approaches to estimate housing supply elasticities see Saiz (2010), Baum-Snow and Han (2021), Anagol, Ferreira, and Rexer (2021) or Galiani, Murphy, and Pantano (2015).

[3]In Colombia, the low-cost housing units are called *Viviendas the Interés Social or VIS*

differentiated good traded in a competitive market[4] and I use the discontinuity and the behavioural responses it induces, as a quasi-experimental source of variation to estimate the primitives of the model. I use a census of all new construction with administrative records for the awarded subsidies from the Ministry of Housing. The construction census contains the universe of new housing projects built in Colombia between 2006-2018. I observe detailed characteristics including, but not limited to, the exact floor spaces, number of rooms, and location.

In the first part of the paper, in sections 2 and 3, I show the expansion of the demand side subsidies, the discontinuity created by the subsidies, and reduced-form evidence of the housing market responding to these subsidies. During my study period, the interest rate subsidy was introduced, the downpayment subsidy increased, and eligibility expanded. As a result, the bunching moves from less than 1 percent of the market share around 2006 to about 7 percent of the market share by 2018. I provide suggestive evidence that the bunching response is driven by changes in housing characteristics and in particular housing size. Households buy housing units up to 30 percent smaller to take advantage of the subsidy.

To rationalize the observed equilibrium responses, I introduce the economic model in section 4, and the identification and estimation strategy in section 5. The economic model introduces the nonlinear incentives created by the Colombian subsidy scheme to a standard model allowing for heterogeneity in supply and demand and product differentiation.[5]Households are heterogenous in income, developers have different productivity levels and housing units different in their size. I use the model to show how the notch creates incentives for developers and households to bunch at the threshold and to explain how the observed equilibrium is compatible with buyers and developers changing the type of units they buy to take advantage of the subsidies.The bunching moments provide information about the trade-off for developers and households between choosing their optimal choice without receiving any benefit and buying the biggest house, qualifying for the subsidy.

To identify the model primitives, I propose an identification strategy based on a two-step procedure implemented in the hedonic equilibrium literature. The first

[4]The original approach, which I follow, assumes perfect competition and a continuum of products. However these assumptions can be relaxed. For examples Bajari and Benkard (2005) proves the existence of a price function even without these two assumptions. The relaxation of these assumptions to a setting with nonlinear incentives is left for future work.

[5]In particular I adapt an hedonic equilibrium or sorting equilibrium model. S. Rosen (1974) adapted the model used for labor markets to study the housing market. For a review of the general approach see Kuminoff, Smith, and Timmins (2013) or Greenstone (2017). For recent applications see Epple, Quintero, and Sieg (2020) and Chernozhukov, Galichon, Henry, and Pass (2021).

step relies on the reduced form analysis from the first part of the paper. In particular, I recover the implicit price function, the behavioural responses induced by the subsidy, the subsidy size, and the relationship between the number of units built and unit size. In the second step, I deviate from the approach used to estimate the primitives of an hedonic model and propose an alternative identification strategy. The discontinuity and estimated behavioural responses allow me to see two points on the same indifference and offer curves for the marginal buncher. I use this and the parameters from the first step to estimate the shape of the utility and cost function.[6]

I find an elasticity of substitution between housing and consumption of other goods of around 0.9. This means that the utility function is close to a Cobb Douglas and housing and consumption of other goods are gross substitutes. I use the economic model and estimated parameters to evaluate how the marginally subsidized households and developers benefit from the subsidy scheme. On the demand side, I compare their utility levels in two counterfactual scenarios, one where they do not get subsidies and another where they receive a subsidy but they do not need to reduce housing size to access it. In both cases, I assume the implicit price for housing size does not change. I find that throughout my study period, with the increase in the subsidy amount, the utility level is 4.5 percent higher relative to the scenario with no subsidies. If the household did not have to reduce their consumption and still get the subsidy, their utility would be 2.8 percent higher. [7]

The estimated parameter of the cost function decreased from 2.5 at the beginning of the period to 1.7 at the end. I calculate the implied marginal costs and profits for the marginally subsidized developers. Developers have higher marginal costs when producing at the price cutoff. However, because of the tax refunds, their profits are higher. I compare the observed equilibrium with the counterfactual scenario where households receive the subsidy but developers do not receive tax refunds. Between 2006 and 2009, their profits would be 5 percent lower, but in 2016 after the subsidy's expansion, they would perceive even higher losses of about 14 percent. If developers do not receive tax incentives, they would be worse off than in a situation without subsidies, suggesting that the tax incentives are important to avoid potential developer's exit and unmatched subsidized housing demand. These results and

[6] I borrow this identification insight from Best, Cloyne, Ilzetzki, and Kleven (2019) and apply it to my setting. Best et al. (2019) use the same identification ieda to estimate the interterporal elasticity of substitution (IES) from the behavioral responses induced by notches in the interest rates for loan refinancing.

[7] This comparisons could be more informative if expressed in dollars using compensated or equivalent variation. Including this is work in progress and will be included soon.

welfare analysis are presented in section 6.

Related Work and Contribution

I make methodological and empirical contributions. My major contribution is to provide a method to recover structural parameters using bunching responses in a vertically differentiated product market equilibrium. This method complements the approaches used in the bunching literature and provides a new identification strategy to recover model primitives in the sorting or hedonic models. I use the bunching evidence and moments to estimate the structural parameters of economic models as done recently, in other settings, by Einav, Finkelstein, and Schrimpf (2015) in the drugs market, Best et al. (2019) in the mortgage market or Chen, Liu, Suárez Serrato, and Xu (2021) in incentives of R&D in China. In contrast to this approach, alternative approaches implemented, for example by (Saez, 2010),(Chetty, Friedman, Olsen, & Pistaferri, 2011), use the bunching moments to derive reduced form elasticities and used them as sufficient statistics for welfare analysis.

Second, my paper provides additional evidence of bunching in the housing market, a relatively unexplored setting. There is evidence of bunching in the density of mortgages with notches in the interest rate schedule. These bunching responses are used to estimate the interest rate elasticity of mortgage demand (DeFusco & Paciorek, 2017), or the inter-temporal elasticity of substitution (Best et al., 2019). Best and Kleven (2017); Kopczuk and Munroe (2015); Slemrod, Weber, and Shan (2017) report housing transactions bunching responses around notches in transaction costs.[8] More closely related to my paper Carozzi, Hilber, and Yu (2020) provide evidence of bunching in the UK as a response to the housing program *help to buy*, a similar program to the one study in this paper. McMillen and Singh (2020) show that apartment rents cluster at values near the fair market rent in Los Angeles, USA. My method, or the insights used in this paper, could be used in those settings to recover the structural parameters of an equilibrium model with vertical differentiation.

The final contribution is to the housing policy literature. Some papers exploit ex-

[8]Building on the literature on nonlinear budget sets (Moffitt, 1990; Eissa & Hoynes, 2006; Quigley, 1982; Hanoch & Honig, 1978; Blinder & Rosen, 1985), and with the increasing availability of administrative data, there is an increase in papers using bunching around cutoffs, introducing kinks and notches in individual's budget sets or firm profits. These papers typically use bunching around notches or kinks to learn about relevant economic parameters such as labor supply elasticity to taxes,(Chetty, Friedman, & Saez, 2013; Chetty et al., 2011; Kleven & Waseem, 2013). Bunching has also been used to study the minimum wage (Cengiz, Dube, Lindner, & Zipperer, 2019; Harasztosi & Lindner, 2019; Jales, 2018), teachers Incentives (Diamond & Persson, 2016), overpay hours (Goff, 2021; Bachas & Soto, 2018; Abel, Dey, & Gabe, 2012), marriage market (Persson, 2020), Crime, (Goncalves & Mello, 2021) among others.

perimental variations in lotteries used to allocate over-subscribed social housing.[9] This paper complements the existing literature by providing evidence on an under-studied type of policy for a developing country and by focusing on the effect on the housing market. This literature is an important input for the intellectual and political debate regarding which approach is the best to guarantee affordable housing. Some of the fundamental questions are: should we build public housing or should we rely on the the housing market? What type of government intervention is more effective: Subsidies, taxes, or regulations, like rent control?[10] If we provide subsidies, should we subsidize developers, households or both?[11] What is the incidence of such subsidies or taxes?[12]

II. Subsidies Over-time and Notch

In this section, I introduce the subsidies and discontinuities that allow me to study the effect of housing subsidies on the housing market. It describes the subsidy expansion and shows how the discontinuity creates incentives to bunch at the price cutoff.

A. Institutional Context and Discontinuity

Institutional Context. Colombian housing policy aims to provide a decent home and suitable living, reduce housing deficits, and achieve the dream of being a country of homeowners.[13] Since the '90s, Colombia and other Latin America countries changed their approach, moving from state-provided housing to a market-based solution based on subsidies. This was promoted by multilateral organizations like the World Bank and the Interamerican Development Bank (IDB) called ABC (from Spanish, *Ahorro*-Savings,*Bonos*-Bonds, *Creditos*-Credit). This policy approach is to incentivize the purchase and construction of low-cost housing through subsidies to

[9]For example see Kumar (2021), Franklin (2019) and van Dijk (2019).

[10]Glaeser and Luttmer (2003) Diamond, McQuade, and Qian (2019)

[11]LIHTC, Baum-Snow and Marion (2009), Soltas (2020). Sinai and Waldfogel (2005), the US subsidies for affordable housing in the US are concentrated on rent subsidies and not subsidies to buy a house Housing vouchers: Collinson and Ganong (2018) McMillen and Singh (2020). Home to buy in the UK Carozzi et al. (2020).

[12](Quigley, 1982; Poterba, 1992; Galiani et al., 2015; Geyer, 2017)

[13]The first and second goal are based on Article 51 of the Colombian constitution. The goal of being a country of homeowners appears on the last three governments pans PND (see for example p104 PND 2002-2006 or translated quote in the appendix **??**). The desirability of this policy approach is beyond the scope of this article. However, this is an open question in the academic debates even outside economics (Pattillo, 2013), and the public debate, blog post and The economist special edition. This paper intends to inform that debate but is not a direct answer to it.

households and their developers. On the demand side, the principal policy tools are mortgage assistance through a down payment subsidy and a subsidized interest rate. On the supply side, the policy tool is a tax refund for developers who build low-cost housing.

The discontinuity. The policy design relies heavily on the definition of low-cost housing. Most of the subsidies apply only to households and developers buying and building low-cost housing, which is a unit with a market price below an arbitrary threshold equal to 135 times the monthly minimum wage (mMW).[14] This arbitrary threshold is the same for all cities, and the change overtime is only because of changes in the minimum wage.[15] There is an additional definition creating a similar discontinuity at a lower price cutoff. Housing units below $70 \times mMW$ classify as lowest-cost housing. This cutoff defines eligibility for some subsidies for the extreme poor and affected by forced displacement or natural disasters. This paper focuses mostly on the subsidies targeting the population buying low-cost housing units.

B. Subsidies Over-time

The sub-periods. During my study period, there are some important changes to the household's subsidies. The interest rate subsidy was introduced, and the subsidy and eligibility increased. As a result, the government expenditure targeting the purchase of low-cost housing more than doubled during this period. Based on the policy changes and to study how the housing market responds to changes in the generosity of subsidies, I divide my study period into four subperiods corresponding to a distinct set of policies available.

The four periods are:

06-08 Down-payments to formal employees (baseline).

09-11 Formal employee Down-payment+Interest Rate.

[14] In Colombia the minimum wage is adjusted every year based on the inflation. Figure 5 in the appendix 3

[15] This price limit is set by the government National Development Plan. The price limit was the same from 1997 until 2019. In 2019, with the law 1467 of 2019, the price limit increased to 150 m-MW for the 5 larger cities (including the metropolitan area) and remained the same in the other cities. Even tough the law came into effect in August, it was anticipated before (see for example a from a newspaper article is Tiempo (2019) from February 2019, or a report from the minister of housing from may (Ministerio de Vivienda, 2019) A low-cost housing unit (VIS) is a house whose total price is below a threshold of 135 monthly minimum wages (around 40 Thousand Dollars) and a lowest-cost unit (VIP) if, is below a threshold of 70 times the monthly minimum wages (around 20 Thousand Dollars)

12-15 Unstable period with rapid changes in the interest rate subsidy and the existence of programs targeted at the extreme poor.[16]

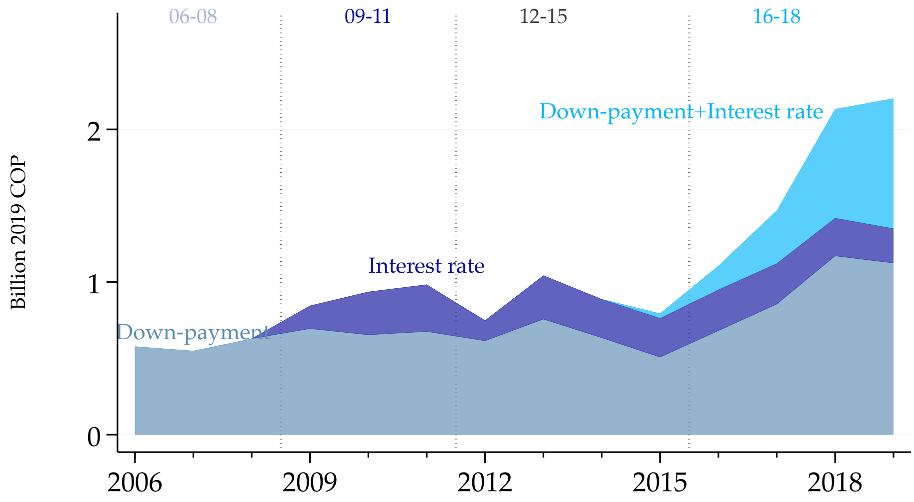
16-18 *Mi Casa Ya* (Down-payment+ automatic Interest rate subsidy) and increase in downpayment subsidy.

Subsidy expansion. The **gray blue** area in Figure 1 shows the total government expenditure from 2006 until 2018. The expenditure on downpayment subsidies was stable until 2015, where there is an increase in the subsidy's size. The **dark blue** area in Figure 1 shows the total government expenditure on subsidized interest rate. The number of households receiving this subsidy where stable overe time but government expenditure slightly decrease due to lower interest rate.[17] The **light blue** shows the expenditure related to the program MCY, which provides downpayment assistances and covers a reduction in the interest rate.

[16] *100 thousand free housing*, and VIPA subsidy for vulnerable population.More details in the appendix 3.

[17] To obtain the government expenditure, I calculate the total savings on mortgage payments induced by the discount at the interest rate. I calculate the monthly payments of each loan using the administrative records for the subsidy and the formula for monthly payments on a mortgage,$L_{monthly} = L \cdot \kappa(i_h, n)$ with $\kappa(i_h, n) = \frac{\frac{i_h}{12} \cdot \left(1+\frac{i_h}{12}\right)^{12 \cdot n}}{\left(1+\frac{i_h}{12}\right)^{12 \cdot n} - 1}$ Where $i_\tau = i - i_{subsidy}$, $i_{subsidy}$ is the interest rate discount, n is the loan term in years, L is the loan amount. Then the government cost is the difference in the amount paid by the households and the amount received by the bank. In particular, $\tau^i = \sum_{t=1}^{84} L_{month}(i, n)(i, n) - L \cdot \kappa(i_\tau, n)$, the sum of monthly payments during 7 years, the period when the subsidy applies.

Figure 1: Total Government Expenditure in Demand Subsidies Overtime



Note: This Figure shows the evolution of total government expenditure by type of subsidy. The Down-payments are the subsidies awarded to employees affiliated to family funds. Interest rate represent the total amount pay by the government to the banks corresponding to the interest rates payments. I assigned the total amount to the year of the subsidy assignment. I calculated this amount using the administrative data containing detailed information on each loan. Mi Casa YA corresponds to the payments on interest rate and the downpayment subsidy. Source: Administrative records from Minister of housing. More details about the data in appendix 3

Supply Subsidy–VAT tax refund. In 1995, a couple of years after the beginning of the down-payment subsidies, and to encourage developers to build low-cost housing, the government introduced a VAT tax refund. Developers get up to 4 percent of the sale price of each unit in the refund of taxes paid in construction materials.[18] I include this subsidy in the analysis.

C. The Notch

The combination of the arbitrary definition of low-cost housing and the different policy tools explained in the previous section creates discontinuous incentives or notches around the cutoff defining low-cost housing. The notch increases over time as a response to introducing new programs and the increase in the subsidy's size.

Relevant Prices. There are three different prices given the subsidy scheme. Transaction or market price, **P**. Developers Price-$\mathbf{P}^{\delta}$ or the per unit price developers receive

[18]This policy instrument was first introduced in the 1995. Even-thought it has been regulated by different laws and acts, e.g., law 1607 of 2012 or the act 2924 of 2013.(Camacol (2016) p.25.) it has been always the same incentive caped at 4% of the value of each unit.

after including the tax refunds. Households price-$\mathbf{P}^{\tau}$, or the price households paid net of subsidies. The difference between these prices is fundamental to uncover the effect of these subsidies on the housing market.Formally,

$$P^{\delta} = P \cdot (1 + \delta)$$
$$P^{\tau} = P - \tau$$

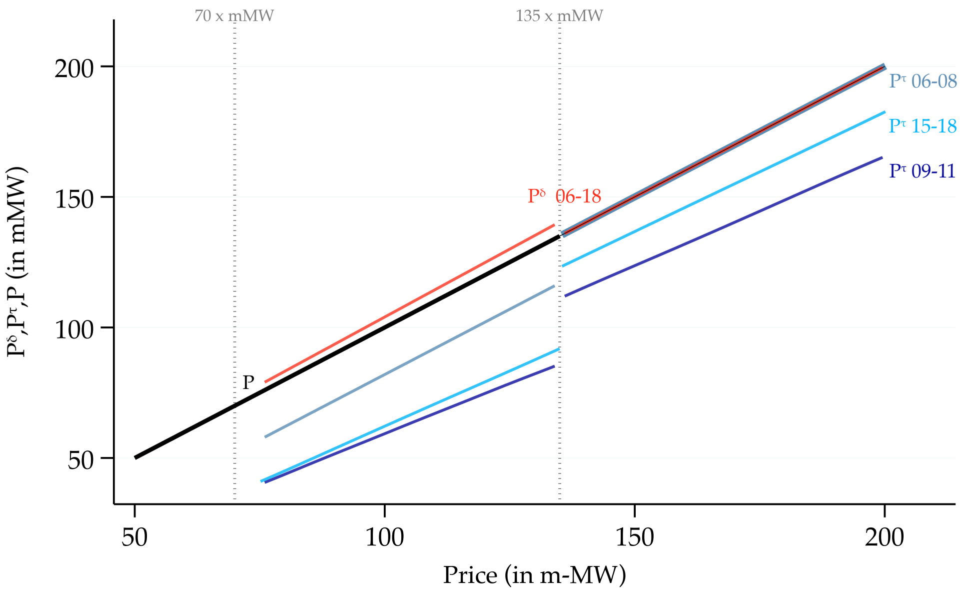
where, $\delta = 4\%$ is the tax refund rate, $\tau = \tau^{m} + \tau^{i}$ is the total amount of money a household receives from the government. τ^{m} represents the money received for the down-downpayment and τ^{i} is the money received from the interest rate discount.The demand subsidy depends on the down payment assistance which is a fixed amount independently of the housing price and the savings from the interest rate discount which depends on the size of the mortgage and therefore it is related to the housing price.

Figure 2.3 shows the notch generated by the subsidy scheme. On the x-axis, I represent the market price P, and on the y-axis, I represent the price received by developers $\mathbf{P}^{\delta}$ or paid by households $\mathbf{P}^{\tau}$. The 45-degree black line represents the market price. The red line is the price received by developers $\mathbf{P}^{\delta}$, the blue lines represent the households price $\mathbf{P}^{\tau}$. There are 3 lines depending on the interest rate subsidy scheme available in each period.

Notch. If the price is below the cutoff, developers get the tax incentives, then the red line is above the black line. A household buying a housing unit below the cutoff qualifies for the subsidy and pays less than the market price. The gap between the black lines and blue lines is the money paid by the government τ. Because housing units with a price above the price cutoff can get an interest rate subsidy, the blue lines on the right of the cutoff are below the black line. But, there is always a notch for the household's price at the cutoff. The periods with interest rate subsidy, have a different slope in the household's price because the subsidy is higher as the mortgage increases. I calculate the government expenditure in interest rate payments using a typical mortgage at each price level.[19] This figure illustrates how the subsidy scheme creates incentives for developers and households to build and buy housing units with a price at or below the cutoff.

[19]For more details on the data sources and the mortgages see appendix 3

Figure 2: The Notch



NOTE: This figure compares the **market price P**, the price received by developers P^δ and the price paid by households net of subsidies in blue . The three different blue lines correspond to the three subsidy schemes available during my study period,P^τ **06-08**,P^τ **09-11** and P^τ **16-18**. The price paid by households is $P - \tau^m - \tau^i$, where τ^m, is a transfer from the government for the down-payment and does does not depend on the house price,τ^i are the savings in interest rate payments, because this depends on the mortgage I calculate it, taking a typical mortgage at each market price using Administrative Records from the Minister of Housing.

Notch overtime. The notch on the demand side increases overtime. The gray blue line shows the household price when only the downpayment subsidy was available. Before the government introduces the interest rate subsidy, households buying a unit priced above the cutoff pay the full price. Then, in the figure, the black and blue lines coincide above the cutoff. The dark blue line shows the price paid by a household that gets the down payment subsidy and the interest rate subsidy during the period 09-11. The interest rate is also available if households get a unit above the price cutoff, but the discount is smaller. The two subsidies combined increase the discontinuity or notch at the cutoff. The light blue line shows the price paid by households who get the two subsidies after introducing the program *Mi Casa Ya* and the increase in the down payment subsidy. During this period, there was a drop in the interest rate and therefore the interest rate subsidy was lower. This explains why the price paid by households below the cutoff is similar in the periods 09-11 and 15-18 even if the down payment subsidy is higher. It also explains why the price in 15-18 is lower above the cutoff. Despite these changes in the interest rate, the notch increases during this period.

The period between 2012 and 2015 experiences many changes. Besides the 100 thousand free housing units priced at $70 \times mMW$ or below the interest rate, the subsidy changed many times. Although, for completeness, I include this period when presenting the data and results; I see it as a transition period and therefore pay little attention to it.

The notch size. Table 1 shows the size of the jump at the cutoff during my study period, and the number of assigned subsidies for each program. There are around 45 thousand households who receive the downpayment subsidy each year, with slight variation across years, around 22 thousand households receiving the interest rate subsidy. Households can get both supports, but they have to apply separately to each program. Around 17 thousand households by year get the subsidy from *Mi Casa Ya*, which grants both subsidies.

Table 1: Notch and number of subsidies by period

	Notch *(in mMW)*			Subsidies *(in thousand)*		
	τ^M	τ^i	τ	*downpayment*	*i rate*	*Mi Casa Ya*
2006-2008	18.0	.	18.0	47.1	.	.
2009-2011	20.0	5.85	25.9	46.4	16.7	.
2012-2015	19.9	9.55	29.5	41.1	22.2	.
2016-2018	25.3	7.24	32.6	44.5	23.4	16.8

Note: This table shows the size of the notch in figure and by period and differentiating the discount coming from the interest rate subsidy and the discount from the down payment assistance. It also shows the number of subsidies (in thousands) assigned to each type of program by year, downpayment, interest rate, and the two together with *Mi Casa Ya*. The number for each period is the average number.

III. Housing Market Responses

This subsection introduces the housing market data and the main descriptive facts. I present evidence of bunching in housing price, I introduce the hedonic price for housing characteristics and the definition of a standardized housing unit. I use this transformation to show the bunching overtime, construct a counterfactual distribution, and explore the behavioural responses induced by the subsidy.

A. Data

The data is a monthly census, called *Coordenadas Urbanas*, collected by the Colombian Chamber of Construction-CAMACOL and containing all new construction units built in 126 Colombian municipalities from 2006 to 2018.[20] The unit of observation is a housing unit type, e.g., if there are three different apartments in a housing project, a studio, one-bedroom, and two bedrooms, I observe the price and characteristics of each of these. I observe all housing projects of 300 m^2. The census excludes small single-family homes and informal housing. It does not contain information about resale of existing housing units. While this is a limitation of the data, the subsidies apply only to new housing, so at least it covers the directly affected part of the market.

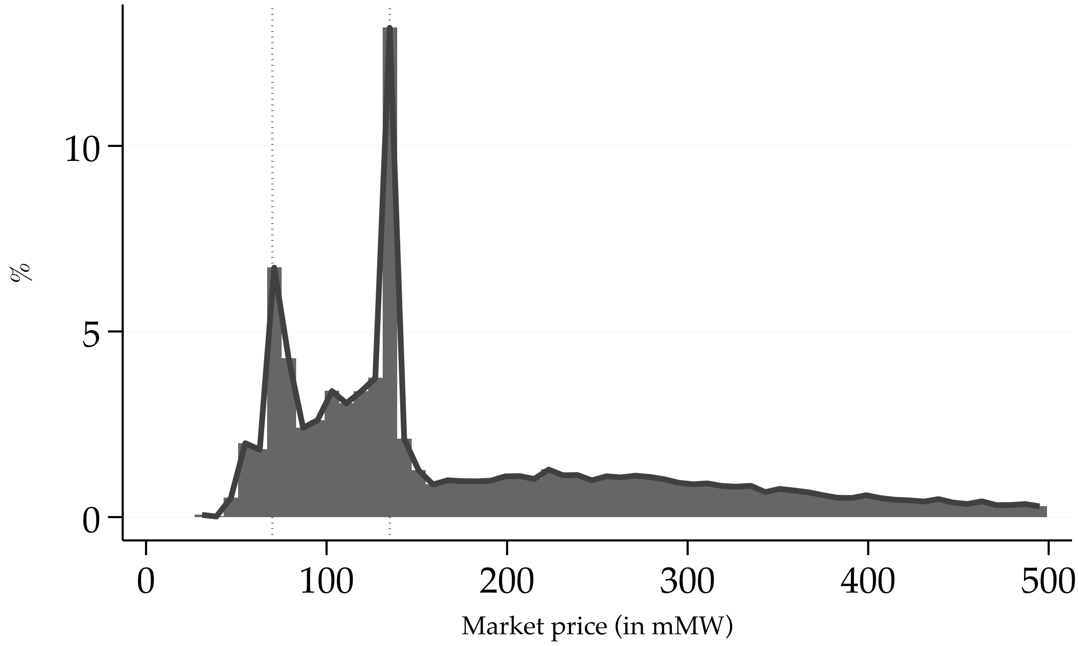
I observe *general characteristics* of the house such as the unit size, location including the exact latitude and longitude coordinates, number of rooms, quality of appliances, estrato, which is an index summarizing neighborhood quality, and *Developers and project characteristics* like firm ID, and the number of units built in each project. The data also includes detailed characteristics of the project, including the number of parking spots, the number of towers built, the lot size,an indicator function equal to 1 if the units are apartments and 0 if they are single family units, among other details of each project. Finally, I observe the *sale price* at different stages of the construction process. To ease the comparison, I take the price at the beginning of the construction of the project. All prices are in 2019 COP or Monthly Minimum Wage mMW. In Colombia, there is a national monthly minimum wage, which is adjusted every year based on inflation. See figures 5 in the appendix 3. In most of the analysis, I express the price in mMW to make it comparable with the price cutoff defining low-cost housing units.

B. Bunching in Observed Market Outcomes.

Bunching around the price limit. Figure 2.3 shows how the subsidy scheme creates incentives for households and developers to buy and build housing units priced at or below the cutoff. To explore the market response to these subsidies, Figure 3.2 shows the distribution of units by market price for all years and cities in the data. The figure shows a sharp and clear excess mass, or bunching, around the price cutoff defining low-cost housing.

[20]Not all cities have information starting in 2006, the census expanded its coverage overtime.

Figure 3: Bunching around the low-cost housing's price limit



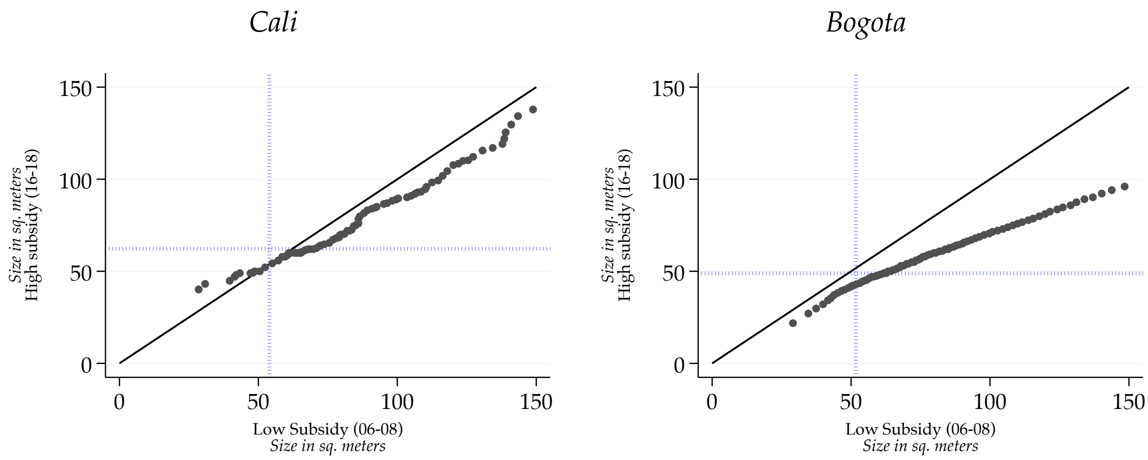
NOTE:This figure shows the distribution or the market share of housing units by sale price (expressed in (mMW). The dashed lines are the cutoffs defining *low-cost housing* and *lowest cost housing*. The figure shows all the units from 2006 to 2018 in all the cities. The spike at *lowest cost housing* is mostly explained by the 100 thousand free housing units granted by the government between 2012 and 2015.

Market adjustment. How does the market adjust to reach this equilibrium? The mechanism explored in this paper is that households and developers adjust the characteristics of the housing units they buy and produce to take advantage of the subsidies. Figure 4 provides suggestive evidence that the subsidy scheme affects that housing stock characteristics. Moreover, the construction sector is perceived as highly competitive and developers have no incentive to build bigger units when, for the same price, households would buy smaller ones.[21] An alternative explanation is that households and developers buy and produce the same type of units they would buy and produce in the subsidy's absence, but developers reduce the price for units above but close to the cutoff, allowing households to get the subsidy. Although this is a possibility, the arguments in this paragraph suggest that this is an unlikely scenario and therefore I focus on changes in housing characteristics.

[21] This argument will be clearer when I introduce the economic model in the next section. Also note that this argument applies for any characteristics that imply any cost for developers.

Size Response. Figure 4 shows the quantile to quantile plots for housing size at the beginning and at the end of the study period for two different cities (More cities are in the appendix Figure 2). During this time, the subsidies increased substantially. If the distribution of housing size did not change from the beginning to the end of the study period, the black dots should be on the 45 degree line. The blue dotted lines show the average size of a subsidized house. Housing units get smaller after the percentile corresponding to the average housing size getting the subsidy, suggesting that the equilibrium size responds to the increase in the subsidies.

Figure 4: Q-Q plots for housing size. Low vs. high subsidy periods

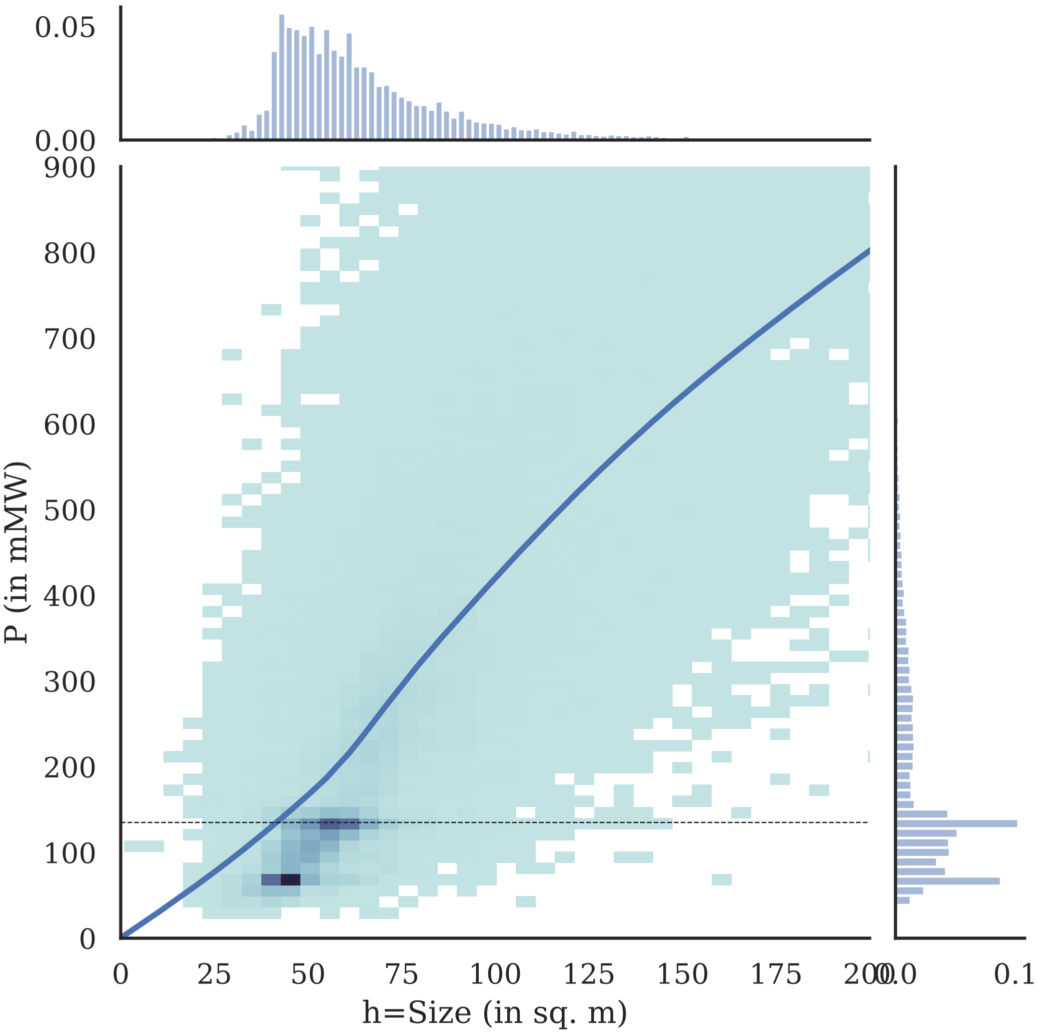


Note: This figure shows the quantile to quantile plot for observed housing size in square meters for two representative cities, Cali and Bogota. The y-axis shows the size at the end of the period, when subsidies are higher, and the x-axis shows the size at the beginning of the period when subsidies are low. The dotted vertical and horizontal lines show the average size of subsidized units. The dots represent the same quantiles in both years. If there are no changes in housing size, they would be in the 45 degree line. Instead, the figure shows how there are changes in size at the quantiles near the average subsidize house.

Figure 5 shows the joint densities of unit size and total price for all years, cities, and unit types. The marginal densities are next to the axis, and the property price density in the x axis is equivalent to figure). Color intensity represents the joint density. In each submarket, heterogeneous agents are buying and selling different housing units. The same money may buy bigger housing units in separate submarkets, therefore agents cluster at different housing sizes which sale price is at or below the cutoff.

Main housing characteristic. It is difficult to summarize housing units into a single variable as they differ in many dimensions. However, focusing on a single characteristic makes the empirical analysis and modelling tractable. In this paper, I focus on housing size for several reasons. First, I my data includes it, which is an advantage because size is it is uncommon to observe it. It is a natural choice because it is a continuous variable whose measurement is incontestable, square meters. Finally, conditional on other characteristics, people prefer larger houses which guarantee a monotonic relationship between size and prices.[22].

Figure 5: Observed Market Equilibrium



Note: This figure shows the joint and marginal densities for housing size (x-axis) and price (y-axis). Darker dots inside the graph represent a higher market share. The figure contains all cities, in all years, and all the different unit types, i.e., single-family homes, multifamily homes, condos, two bedrooms, one bedroom, etc,.

[22]Housing quality or the distance to the Central Business District (CBD) is a good alternative variable. However, quality is hard to measure, and distance to the CBD may have a non-monotonic relationship with income.

C. Hedonic Price and Standardized Unit

This subsection introduces the hedonic price function, which plays two roles. First, it allows me to recover the marginal willingness for housing size and the other observed characteristics. Second, I use this price function to convert all housing units into a standard unit that only changes in size.

Implicit price for housing size.

The solid line in figure 5 shows the unconditional nonparametric positive relationship between size and price. This pattern follows the expected positive relationship and suggests a nonlinear relationship. However, this unconditional relationship may not represent the equilibrium marginal willingness to pay and supply housing size, they may be unobservable characteristics affecting size and price, creating bias. I follow common practice in the hedonic literature to estimate the equilibrium implicit price of size.[23] Equation 1 represents a general specification for the price function. Where s_{ltc} is housing size, X_{ltc} is a vector containing all other housing characteristics, and ω_{ltc} represents the residual containing unobserved characteristics.

$$P_{ltc} = \rho\left(s_{ltc}\right) + \Gamma' X_{ltc} + \omega_{ltc} \tag{1}$$

I observe a unit type l in city c at time t. I assume that the housing price is additive and separable in housing size s_{ltc}, the other characteristics included in X_{ltc} and unobserved ω_{ltc}. X_{ltc} which includes location, quality, number of rooms, and neighborhood quality index, among others. ρ relates housing size and unit price P, and is the implicit price for housing size. I assume a parametric function specification for ρ. In particular,

$$\rho\left(s_{ltc}\right) = \rho_1 \cdot s_{ltc} + \rho_2 \cdot {s^2}_{ltc} \tag{2}$$

To estimate the implicit or hedonic price, I rely on independence conditional on observable characteristics:[24]

$$\mathrm{E}\left(s_{ltc} | X_{ltc}, \omega_{ltc}\right) = 0 \tag{3}$$

[23](Bishop and Timmins (2019),Bajari and Benkard (2005),Epple et al. (2020) or (Bajari, Fruehwirth, Kim, & Timmins, 2012)

[24]Bajari and Benkard (2005) propose three different identification assumptions; i) Independence conditional on observables, ii) Option packages and iii) instruments. My setting and data allows an implementation of each of the three identification approaches. However, the results presented in this paper rely on the first condition.

Independence conditional on observables. It is common to rely on conditional independence to recover the implicit price function of a certain characteristics.[25] In my setting, I observe a rich and unique set of controls. This includes, the exact location of the unit, general characteristics of the house including the number of rooms, neighborhood quality index[26].

Discussion about the assumptions. This assumption can be problematic in many settings. For example, Chay and Greenstone (2005) show that using a hedonic model to recover the marginal willingness to pay for air quality without using instruments generates biased results. Omitted variables can generate a bias in my setting, however I present two facts that are reassuring. First, in contrast to air quality, the hedonic regression does not show the opposite of the expected sign. Second, when I include characteristics such as an indicator function equal to one, if a house extension is possible (e.g., extra bathroom or bedroom), the size coefficients do not change. This is a type of potentially unobserved characteristics by the econometrician related to size and the fact that including then does not affect the size coefficients is reassuring. However, this does not rule out the fact that other omitted variables could bias the result. For example, if changes in price generate the bunching with no change in size, the error term could be correlated with size, particularly for observations around the price cutoff.

Standardized Housing and Unit Size

To make all housing units comparable, I use the hedonic price function to standardize all housing units. In particular, I use the estimates of equation 1 to convert all housing units into a standard unit.

This hedonic price estimation decomposes the unit price into observed and unobserved characteristics. The standardized housing size, which I call h, is the size of a housing with average characteristics that will cost the same as the observed price.

$$\rho\left(h_{ltc}\right) + \rho\left(\bar{s}_{ltc}\right) + \Gamma' \bar{X}_{ltc} + \bar{\omega}_{ltc} = \rho\left(s_{ltc}\right) + \Gamma' X_{ltc} + \omega_{ltc} \tag{4}$$

$\bar{X}_{ltc}$, $\bar{\omega}_{ltc}$ are the average observed and unobserved characteristics observed in the

25

26 These are codes from 1 to 6 called estratos that summarize the quality of the block, they also have different property taxes (in some cities) and prices for utilities. For more details, see (Uribe, 2021)

data. Solving for h in the equation 4, I get the standardized size measure,

$$h_{ltc} = \rho^{-1}\big(\rho\left(s_{ltc}\right) + \Gamma'\left(X_{ltc} - \bar{X}_{ltc}\right) + \left(\omega_{ltc} - \bar{\omega}_{ltc}\right)\big) \tag{5}$$

Intuitively, this means that if a house is more expensive because of the access to certain amenities or because it has more bathrooms, I convert this characteristic into the equivalent square meters that the household could get if they had a standard house.

In my application, I standardize the units in a way that $\bar{P} = \rho\left(\bar{s}_{ltc}\right) + \Gamma'\bar{X}_{ltc} + \bar{\omega}_{ltc}$ is the observed average price for the average house. For the implicit price function, I use a parametric approximation $\rho(s) = \rho_0 + \rho_1 \cdot s + \rho_2 \cdot s^2$.[27]

Figure 6 shows the functional form of the estimated price function for the four different periods. Tables in appendix **??** present different specifications for the price function and the figures for the other cities. The figure 6 shows that the implicit price gradient, representing the marginal willingness to pay and supply, has become steeper.

Implied maximum size of a standard subsidized unit

Given the standardized unit definition, the maximum size for a unit to qualify for the subsidy at the observed equilibrium's marginal willingness to pay and produce is $\underline{h}$:

$$135 \times mMW = \lambda = \rho\left(\underline{h}\right)$$

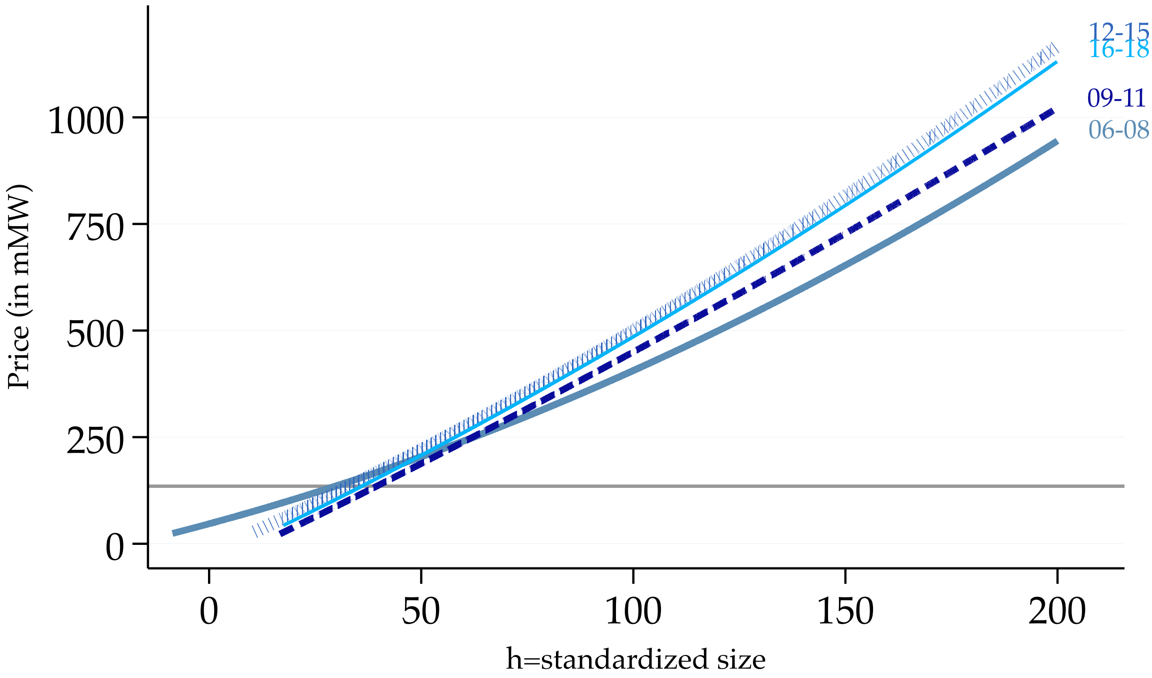
Given a particular assumed functional form,

$$\underline{h} = \frac{-\rho_1 + \sqrt{\rho_1^2 - 4 \cdot \rho_2 \cdot (\bar{P} - \lambda)}}{2 \cdot \rho_2}, \tag{6}$$

In Figure, 6 $\underline{h}$ corresponds to the value of h at which the implicit price intersects the price cutoff (gray vertical line).

[27] The unconditional relationship between size and price in figure 5 suggest that the implicit price function is not quadratic. However, once I include controls in a partially linear model, a quadratic function seems accurate. This parametric approximation makes the inverse function straightforward to calculate.

Figure 6: Implicit price for housing size



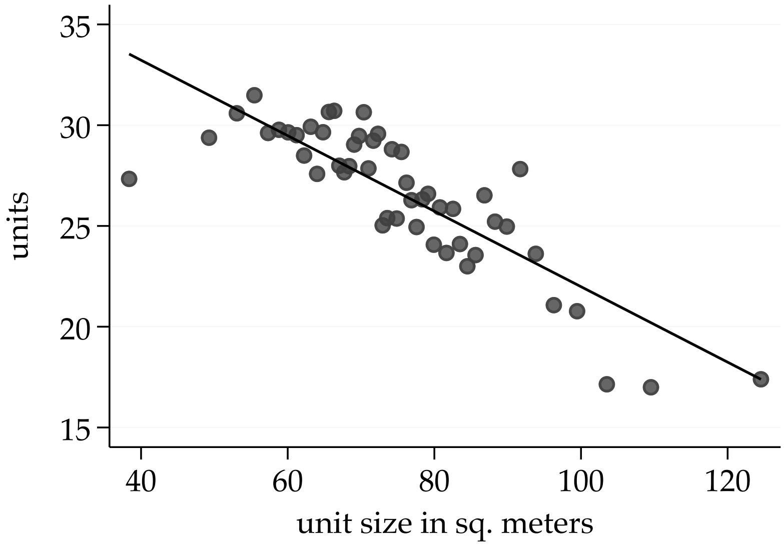
Note: This figure shows the price for standardized sized h by period. Represents the price of the standardized unit by size. The implicit function for size is $\rho(s) = \rho_0 + \rho_1 \cdot s + \rho_2 \cdot s^2$. The controls X included in the hedonic regression in equation 4 used to create the standardized size are: the number of bathrooms, the number of rooms, and an indicator function equal to 1 if the unit is a building and the location, a dummy variable equal to one if the unit has a porch, a studio, storage unit, dressing room, service room, dining and living room, fireplace, kitchen, clothes areas, patio, and potential to extend to an extra bathroom or bedroom and location coordinates, lot size, number of building blocks, apartments per floor, number of floors, total parking spots, and number of building units.

D. Unit supply Function

How do developers respond? One of the principal objectives of the economic model is to address this question in more detail. However, before introducing the model and recovering estimating the equilibrium responses in terms of changes in housing characteristics, I explore the relationship between the unit size and the number of units built. Developers built more housing units when they decide to produce smaller housing sizes. One advantage of the data is that I observe the number of units built by unit type, and therefore I can get empirical estimates of the trade-off between unit size and the number of units and account for it in the model.

Figure 10 shows a bin scatter plot, including a set of controls for unit and project characteristics for all years, cities, and units. The Figure shows a negative relationship between unit size and number of units, which is intuitive and makes sense. Developers make a trade-off between having their preferred housing unit and getting the subsidy.

Figure 7: Unit supply function



NOTE: This Figure shows the bin scatter for the number of units and by unit size after controlling by observable characteristics. In this figure I use the same controls as in figure 6. This figure includes the observations for all years and all cities. Table 2 shows the estimated parameters for this relationship by period with and without controls.

Table 2 shows estimates of the model in equation 7 by period and with and without the set of controls X_{ltc}.

$$Q_{ltc} = \alpha_0 + \alpha_1 s_{ltc} + \alpha_x' X_{ltc} + \epsilon_{ltc}^{Q} \tag{7}$$

The coefficients in table 2 shows the same negative relationship between the number of units built by developers. Including the controls, X_{ltc}, changes substantially the coefficients. In particular, the controls related to the housing project, such as number of buildings and lot size, among others. The slope does not change much during this period, but the constant does change.

Table 2: Unit supply Function

	06-08		09-12		13-15		16-18	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
α_1	-0.17***	-0.05***	-0.13***	-0.04***	-0.16***	-0.05***	-0.18***	-0.07***
	(0.007)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)	(0.008)	(0.010)
α_0	43.66***	63.32**	33.74***	15.01	38.22***	83.92***	42.24***	35.85**
	(1.169)	(20.350)	(0.734)	(9.459)	(0.835)	(18.227)	(1.003)	(11.375)
X_{ltc}	No	Yes	No	Yes	No	Yes	No	Yes
N	11,906	11,889	15,056	15,029	20,950	20,881	15,756	15,418

NOTE: This figure shows the coefficients from equation 7 by period. The set of controls X_{ltc} is the same than the one detailed in Figure 6.

E. Changes in Housing Characteristics to Benefit from the Subsidy

The estimated hedonic price, standardized size, and the implied size cutoff, $\underline{h}$, allows me to rationalize the bunching responses in terms of changes in the housing size of a standard unit. This subsection shows the evolution of the behavioural response in terms of reduction in housing size as the subsidy increases and eligibility grows. To quantify the changes induced by the subsidy,I follow the bunching literature to estimate the excess mass and the behavioural responses, taking the differences between the observed distribution of market shares by size and an estimated counterfactual distribution.

Counterfactual Distribution Estimation

In contrast with figure 3.2, in this section, I present the market shares by standardized unit size, and not unit price, and by period. By doing that, I can interpret the changes induced by the subsidies as changes in the size of a standard unit. Developers and households build and purchase smaller houses to take advantage of the subsidy.[28]

Define $T(h)$ as the change in observed density f_{h^*} relative to the counterfactual

[28]Here, I assume all changes are in terms of the housing size of a standard unit. Although I acknowledge this is a strong simplifying assumption, it makes the analysis tractable. My setup and economic framework introduced in section 4 can be the basis to extend the analysis to separate changes in multiple characteristics, i.e., location or quality, and to include some prices only responses in a setting with developer frictions or imperfect competition.

distribution f_{h_0},

$$T(h) = f_{h^*} - f_{h_0} \tag{8}$$

and Δh as the maximum change agents made to take advantage of the subsidy.

$$\Delta h = \overline{h} - \underline{h} \tag{9}$$

Intuition. The counterfactual is the distribution that would exist in the subsidy's absence. I calculate it fitting a flexible polynomial to the observed density and excluding the observations close to the cutoff. The differences between the counterfactual distribution and the observed distribution reflect the behavioural responses to the subsidy scheme's discontinuous incentives.

Estimation. To estimate f_{h^*} and f_{h_0}, I rely on standard techniques from the bunching literature. To estimate the empirical distribution $\hat{f}_{h^*}$, I calculate the share of units in each bin h_b of size $2 \cdot \epsilon$,

$$h_b = \frac{1}{N} \sum_{l=1}^{N} \mathbb{1} \left[h_l \in (b - \epsilon, b + \epsilon) \right] \tag{10}$$

The estimated observed equilibrium distribution is

$$\hat{f}_{h^*}(h) = h_b$$

To estimate the counterfactual distribution, $\hat{f}_{h_0}$, I predict the observed values for h_b using a flexible polynomial, $l(h_b) = \sum_{p=0}^{T} \iota_p h_b^p$ and excluding a region around the cutoff, $o(h_b; L, H)$ is a function with all the indicator variables for the bins between L and H lower and the upper bound of the excluded area.

$$h_b = l(h_b) + o(h_b; L, H) + v_b \tag{11}$$

Counterfactual distribution: The counterfactual distribution is the predicted density using only the flexible polynomial.

$$\hat{f}_{h_0} = \hat{l}(h_b) = \sum_{p=0}^{T} \hat{\iota}_p h_b^p \tag{12}$$

Bunching. Using the estimated distributions, I can get an expression for bunching or excess mass at $\underline{h}$, and calculate the maximum behavioural change induced by the subsidy Δh

$$\hat{T}\left(\underline{h}\right) = \hat{f}_{h^*}\left(\underline{h}\right) - \hat{f}_{h_0}\left(\underline{h}\right) \tag{13}$$

Equation 13 is the difference between the observed distribution and the counterfactual distribution at the discontinuity point, $\underline{h}$, and it represents the share of individuals who would consume $h \in (\underline{h}, \overline{h})$ in the absence of the subsidy, but consume h in a subsidy scenario.

Maximum behavioural response. The maximum behavioural response, $\overline{h}$ is obtained when the counterfactual and observed distribution coincide.

$$\overline{h} = min[h : h > \underline{h} \text{ and } \hat{f}_{h_0}\left(\underline{h}\right) - \hat{f}\left(h_b\right) = 0]$$

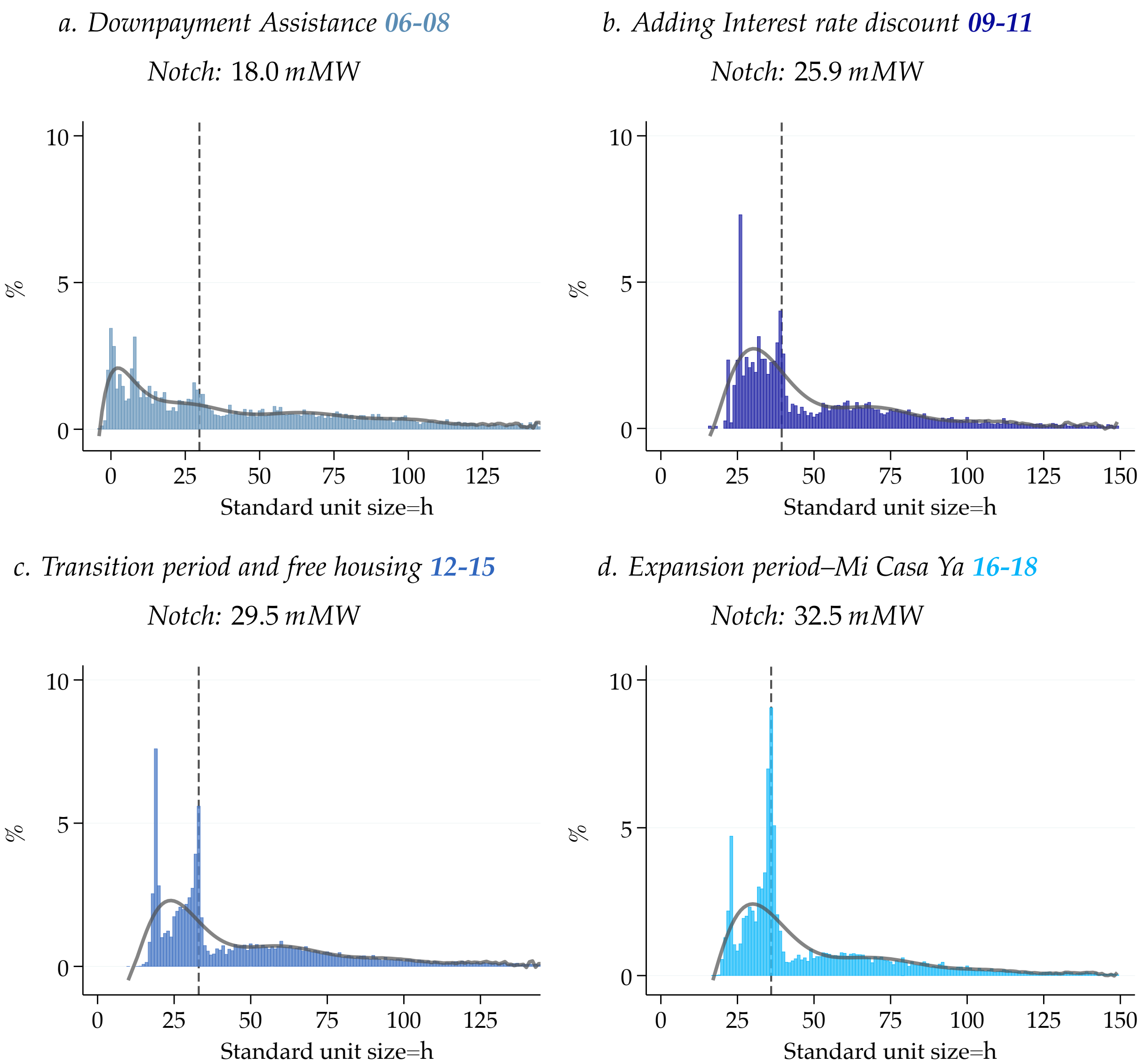
Behavioural responses $\overline{h}$

The main behavioural response I explore in this paper is the trade-off between subsidy benefits' and housing unit amenities, in particular, housing size. The excess mass $\hat{T}\left(\underline{h}\right)$ at the cutoff $\underline{h}$ is the share of households that reduce their housing consumption to get the subsidy. Because this behaviour results in an equilibrium outcome, this corresponds to the response on the supply side. Developers adjust the type of housing they build to meet policy-induced changes in demand.

I exploit the changes in the policy overtime to show how as the notch at the cutoff increases, the bunching increases. This introduces additional convincing evidence that the housing market responds to subsidies. The bunching responses are more pronounced as the government expenditure on subsidies increases. Figure 8 shows the distribution of the standardized units for the periods when subsidies change, and a solid grey line for the counterfactual distribution. Table 3 shows the estimates of the relevant behavioural responses. The subsidy creates a small bunching when only down payment assistance is available (2006-2008). With the addition of the interest rate discount **(2009-2011)**, the there is an increase in the bunching. As expected, the transition years (2012-2015) have a big bunching response in the cutoff defining the housing units that were completely subsidized. Finally, during the subsidy expansion the behavioural responses are more pronounced (2009-2011), the bunching at the cutoff is 2.02 percent of the market share, compared to 4.02 percent of the market share in the transition period, and 7 percent at the end of the period.

When the subsidies are highest.

Figure 8: Equilibrium Density by $\tilde{h}$



Note: This figure shows the market share or distribution of units by standard unit size by period. The different periods represent a different subsidy scheme and the notch increased overtime. The average size of the notch (in mMW) is above each figure. The dashed line vertical line corresponds to the maximum size of the standard unit qualifying for the subsidy, $\underline{h}$. Each observed unit is converted into a standard unit and the size adjusted according to the estimated willingness to pay for each characteristic. The solid gray line represents the counterfactual distribution. i.e., the distribution that would exist in the absence of the subsidy.

Table 3: Behavioral Responses Estimates'

	06-08	09-11	12-15	16-18
$\int_{h_{min}}^{\underline{h}^{-}} T(h)\mathrm{d}h$	1.03	0.86	3.83	7.28
$\hat{T}\,(\underline{h})$	0.50	2.02	4.02	6.97
$\int_{h_{min}}^{\underline{h}} T(h)\mathrm{d}h$	1.53	2.88	7.85	14.2
$\int_{\underline{h}}^{\overline{h}} T(h)\mathrm{d}h$	-0.096	-6.25	-4.13	-3.42
$h_{h^0}\,(\underline{h})$	0.72	1.28	1.06	1.44
h_{min}	26	37	29	32
$\underline{h}$	29.8	39.4	33.0	36.0
$\overline{h}$	40	53	45	49

NOTE: This Table shows the statistics summarizing the behavioural responses induced by the subsidy. Each column represents different periods. $\underline{h}$, is the biggest housing unit qualifying for the subsidy, is the size of the unit size $\overline{h}$, above which households do not reduce there housing consumption to take advantage of the subsidy. h_{min} is the lower point (close to $\underline{h}$) where the observed distribution is above the counterfactual distribution. $T(h)$ is the difference between the observed and counterfactual distribution. The three different integrals show the excess or missing mass across more than one bin. For example, $\int_{\underline{h}}^{\overline{h}} T(h)\mathrm{d}h$ is the missing mass between $\underline{h}$ and $\overline{h}$, $\int_{h_{min}}^{\underline{h}^{-}} T(h)\mathrm{d}h$ is the excess mass excluding the excess at the cutoff $T(\underline{h})$, All the excess mass is calculated by $\int_{h_{min}}^{\underline{h}} T(h)\mathrm{d}h$.

Section takeaways. This section provides compelling evidence that the Colombian housing market responds to the discontinuous incentives generated by the subsidy scheme. Suggestive evidence supports the view taken in this paper that these responses come from households buying smaller housing units to take advantage of the subsidy. How does the supply side adjust to this change in the demand side? How does the equilibrium price set? Is the subsidy to developers necessary to prevent housing rationing?

IV. A Competitive Housing Market Equilibrium Model

This section introduces a housing market equilibrium model. The objectives of the model are. First, provide a framework to rationalize the observed equilibrium and understand the economic behaviour of agents. Second, it describes the equilibrium conditions for this model and the role of the hedonic price function. Third, it motivates a novel identification approach to recover the household's and developers' behavioural parameters.

A. Model Set Up

The proposed model introduces the discontinuous incentives produced by the subsidy scheme to a standard hedonic or sorting model.[29]

Housing. The model allows for housing to be a vertically differentiated product. In this case, all units are standardized as proposed in 3.2 and units differ in its size h. The price of the housing unit P depends on size h, and it is described by the hedonic price function $P(h)$.

Households. Households looking to buy a *new* housing unit are indexed by i. They are heterogeneous on income $Y_i \sim F_Y$.[30]. Households, decide how much housing to buy, h_i and how much to consume on a other goods C_i to optimize utility $U(C_i, h_i; \theta)$, θ characterizes the preferences, and it is the parameter to estimate.

Developers. Developers indexed buy j and heterogeneous in their productivity $A_j \sim G_A$. They decide the size of the housing units they build, h_j to maximize profits.An exogenous function determines the number of units $Q_j = Q\left(h_j; \boldsymbol{\alpha}\right)$. They face building costs $B(h_j, Q\left(h_j\right); \beta)$[31] where β characterizes the cost function and is the parameter to estimate.

Simplifying assumptions. Note that I introduced three simplifying assumptions. First, a perfectly competitive market, i.e., developers cannot individually affect prices, and $P(h)$ is independent of Q. Second, developers only pick the unit size they build. They follow a unit supply function, which is exogenous and differentiable, $Q = Q^S(h; \alpha)$. Third, the building costs depend on $Q(h; \alpha)$ and h, i.e., $B = B\left(Q(h; \alpha), h, A_j; \boldsymbol{\beta}\right)$. These last two simplifying assumptions make it straightforward to specify functional forms for the profit function and offer curves. Allowing for an endogenous choice of Q could be a better characterization, but makes it difficult to obtain a functional

[29] This is a simplified version of an model with heterogeneous households and developers buying housing units of different size. For ease of exposition, I simplify it by assuming a single variable describes the housing. For some examples of these types of models, without a notch in the budget set, see S. Rosen (1974), Epple (1987), Heckman, Matzkin, and Nesheim (2010) or Epple et al. (2020). The literature based on this models is summarized by Kuminoff et al. (2013) andGreenstone (2017). For a survey of the empirical applications see Palmquist (2006).

[30] I call Y_i income for simplicity, but this in also contains wealth, assets and their returns, transfer, etc. , F_Y is the cdf describing the income's distribution

[31] The cost function $B\left(Q, h, A_j; \boldsymbol{\beta}\right)$ is derived from minimizing the production constraints related to producing Q units of products with characteristics h. A_j reflects underlying variables in the cost minimization, i.e., factor prices and production function parameters. Different values of A express different factor prices or productivity among developers. For some discussion about this, see S. Rosen (1974) p.43

form for the offer curve, which is essential in the identification approach. Relaxing this assumption and allowing for imperfect competition is feasible but beyond the scope of this paper.

Equilibrium. When developers and households decide the type of units they buy, they are in practice choosing the developer type to buy from. Then, the equilibrium is an implicit price making the housing units' demanded and produced densities match.

B. Optimal choices

Prices

Section 2 explains that given the subsidy scheme, their three relevant prices, developer, household, and market price.

$$\text{Market:}\quad P\left(h;\boldsymbol{\rho}\right) \tag{14}$$

$$\text{Household:}\; P^{\tau}\left(h,\tau;\boldsymbol{\rho}\right)=P\left(h;\boldsymbol{\rho}\right)-\tau\cdot\mathbb{1}\left[P\left(h;\boldsymbol{\rho}\right)\leq\lambda\right] \tag{15}$$

$$\text{Developer:}\; P^{\delta}\left(h,\delta;\boldsymbol{\rho}\right)=P\left(h;\boldsymbol{\rho}\right)\left(1+\delta\cdot\mathbb{1}\left[P\left(h;\boldsymbol{\rho}\right)\leq\lambda\right]\right) \tag{16}$$

Differences in prices. A household getting a subsidy pays $P^{\tau}\left(h,\tau;\boldsymbol{\rho}\right)$ instead of $P\left(h;\boldsymbol{\rho}\right)$ which is the market price and developers who build low-cost housing can get back the VAT taxes paid for materials. The cutoff, λ to get the incentives are the same on the supply and demand side, $P\left(h,\rho\right)<\lambda=135\,mMW$. The reimbursement of VAT taxes cannot exceed a value δ=4 percent of the value of the house. In other settings where the price can increase, and the limit is set in terms of size, the market equilibrium could be achieved by an increase in price, and δ would represent a premium to build low-cost housing.

The price function $P\left(h;\boldsymbol{\rho}\right)$ can be a continuous and differentiable function for all $h\in\mathcal{H}$. but developer and household price function, $P^{\delta}\left(h,\delta;\boldsymbol{\rho}\right)$, and $P^{\tau}\left(h,\delta;\boldsymbol{\rho}\right)$, are non differentiable at $P\left(h;\boldsymbol{\rho}\right)=\lambda$.

Decision's problem

Households A household $i \in N$ maximize its utility given their income level Y_i. They solve the following optimization problem:

$$
\begin{aligned}
& \max_{h,C} && U(h, C; \theta) \\
& \text{subject to:} && Y_i = P^{\tau}(h, \tau; \boldsymbol{\rho}) + C, \\
& && h \geq 0.
\end{aligned}
$$

Developers Developer's profits $\pi\left(Q(h), A_j; \boldsymbol{\rho}\right)$ are determined by the total revenue minus costs.

$$
\begin{aligned}
& \max_{h} \quad \pi\left(Q(h), A_j; \boldsymbol{\rho}, \delta\right) \\
& \pi = Q(h) \cdot P^{\delta}(h; \delta, \boldsymbol{\rho}) - B\left(Q(h), A_j; \boldsymbol{\beta}\right)
\end{aligned}
$$

Households and developers choose their housing size h to maximize their objective function. Because of the notch in the budget, set, the standard *optimally conditions*, obtained when the price function and bid function or offer curves are tangent, do not correspond to the optimal choice for all households in this setting. Let's define the *tangency conditions*,[32] and the bid and offer functions to characterize the optimal choices.

Bid functions (or indifference curves) The bid functions,$\varphi_D\left(h, Y, \bar{U}; \theta\right)$ represent all the combinations of prices P and unit size h that provide the same level of utility $\bar{U}$ to a household with income Y_i. This is φ_D is such that,

$$
\bar{U} = U\left(h, Y_i - \varphi_D; \theta\right) \tag{17}
$$

Offer function The offer function represents and indifference surface for all possible combinations of prices and size h providing the same profits. φ_j^S represents the price developers are willing to accept at different unit sizes to get a constant level of profits $\bar{\pi}_j$. To define the offer function, I replace the developers' price, $P^{\delta}(h; \delta, \boldsymbol{\rho})$, by

[32]This follows by defining a Lagrangian and taking first-order conditions with respect to h and C and taking the ratio. I am assuming that the composite good has a price $p_c = 1$

φ_j^s, profits by $\bar{\pi}$, and solve for φ_j^s,

$$\varphi_j^s = \frac{B\left(Q^s\left(h;\alpha\right), A_j; \boldsymbol{\beta}\right) + \bar{\pi}}{Q^s\left(h;\alpha\right)} \tag{18}$$

Tangency conditions

Households Households choose their housing size h to maximize their utility. Because of the notch in the budget set, the standard *tangency conditions* do not correspond to the optimal choice for all households. Let's define the *tangency conditions*,[33]

$$\frac{\partial P\left(h, \boldsymbol{\rho}\right)}{\partial h} = \frac{\dfrac{\partial U\left(h, C; \theta\right)}{\partial h}}{\dfrac{\partial U\left(h, C; \theta\right)}{\partial C}} \tag{19}$$

Assuming that equation 19 has a unique solution and using the budget constraint, $P^{\tau}\left(h, \tau; \boldsymbol{\rho}\right) - Y_i = C_i$., we can *solve* for h^*, the housing choice satisfying the *tangency conditions*.[34]

$$h^*\left(Y_i, \tau; \theta, \boldsymbol{\rho}, \lambda\right) = \begin{cases} h\left(Y_i + \tau; \theta, \boldsymbol{\rho}\right) & \text{if } P\left(h; \boldsymbol{\rho}\right) \leq \lambda \\ h\left(Y_i; \theta, \boldsymbol{\rho}\right) & \text{if } \lambda < P\left(h; \boldsymbol{\rho}\right) \end{cases} \tag{20}$$

Developers. On the supply side, the designs satisfying the optimality conditions, $h^*\left(A_j, \boldsymbol{\beta}, \boldsymbol{\rho}\right)$ for a given price function $P\left(h, \boldsymbol{\rho}\right)$ is achieved when developers maximize profits subject to the developers' price being equal to the offer curve. The unit size satisfying the tangency conditions $h^*\left(A_j, \boldsymbol{\beta}, \boldsymbol{\rho}\right)$ and optimal profits $\bar{\pi}\left(A_j, \boldsymbol{\beta}, \boldsymbol{\rho}\right)$ are achieved when the price and offer curves are tangent

$$\frac{\partial \varphi^s\left(h, A_j; \boldsymbol{\beta}, \bar{\pi}\right)}{\partial h} = \begin{cases} \dfrac{\partial P\left(h, \boldsymbol{\rho}\right)}{\partial h} \cdot \left(1 + \delta\right) & \text{if } P\left(h; \boldsymbol{\rho}\right) \leq \lambda \\[2ex] \dfrac{\partial P\left(h, \boldsymbol{\rho}\right)}{\partial h} & \text{if } \lambda < P\left(h; \boldsymbol{\rho}\right) \end{cases} \tag{21}$$

[33]This follows by defining a Lagrangian and taking first-order conditions with respect to h and C and taking the ratio. I am assuming that the composite good has a price $p_c = 1$

[34]It has been discussed in the literature that a sufficient condition for this to hold is to assume a Spence-Mirrlees type single crossing condition. See for example Heckman et al. (2010) p.1573 or Kuminoff et al. (2013)for an overview.

We can solve 21 for h, and get and expression for the tangency conditions,

$$h^*\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho},\lambda\right)=\begin{cases} h\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho}\right) & \text{if } P\left(h;\boldsymbol{\rho}\right)\leq\lambda \\ h\left(A_j;\boldsymbol{\beta},\boldsymbol{\rho}\right) & \text{if } \lambda<P\left(h;\boldsymbol{\rho}\right)\end{cases} \tag{22}$$

Definition of optimizer types.

The demand and supply for housing in this case does not correspond to the optimality conditions in this setting because there is a subset of households for which it is optimal to sacrifice housing consumption to get the subsidy. For developers, it is also beneficial to produce a smaller housing unit to benefit from the tax refund. There are 4 types of households and developers.

1. *Thresholds optimizer* $Y_i=\underline{Y}, A_j=\underline{A}$

$$h^*\left(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda\right)=\underline{h} \text{ and } h^*\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho},\lambda\right)=\underline{h} \tag{23}$$

these are agents who receive the incentives and whose tangency condition is exactly the *size threshold* $\underline{h}$.

2. *Marginally Subsidized* $Y_i\in\left(\underline{Y},\overline{Y}\right), A_j\in\left(\underline{A},\overline{A}\right)$

$$U\left(Y_i-P^\tau\left(h^*\left(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda\right),\tau;\rho\right),h^*\left(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda\right);\theta\right)<U\left(Y_i-P^\tau\left(\underline{h},\tau;\boldsymbol{\rho}\right),\underline{h}:\theta\right) \tag{24}$$

$$\pi\left(Q(h^*\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho},\lambda\right)),\overline{A};\boldsymbol{\rho},\delta\right)<\pi\left(Q(\underline{h}),\overline{A};\boldsymbol{\rho},\delta\right) \tag{25}$$

These agents buy and produce different housing units than the ones satisfying the optimality conditions to take advantage of the incentives.

3. *Marginal bunchers:* $Y_i=\overline{Y}$

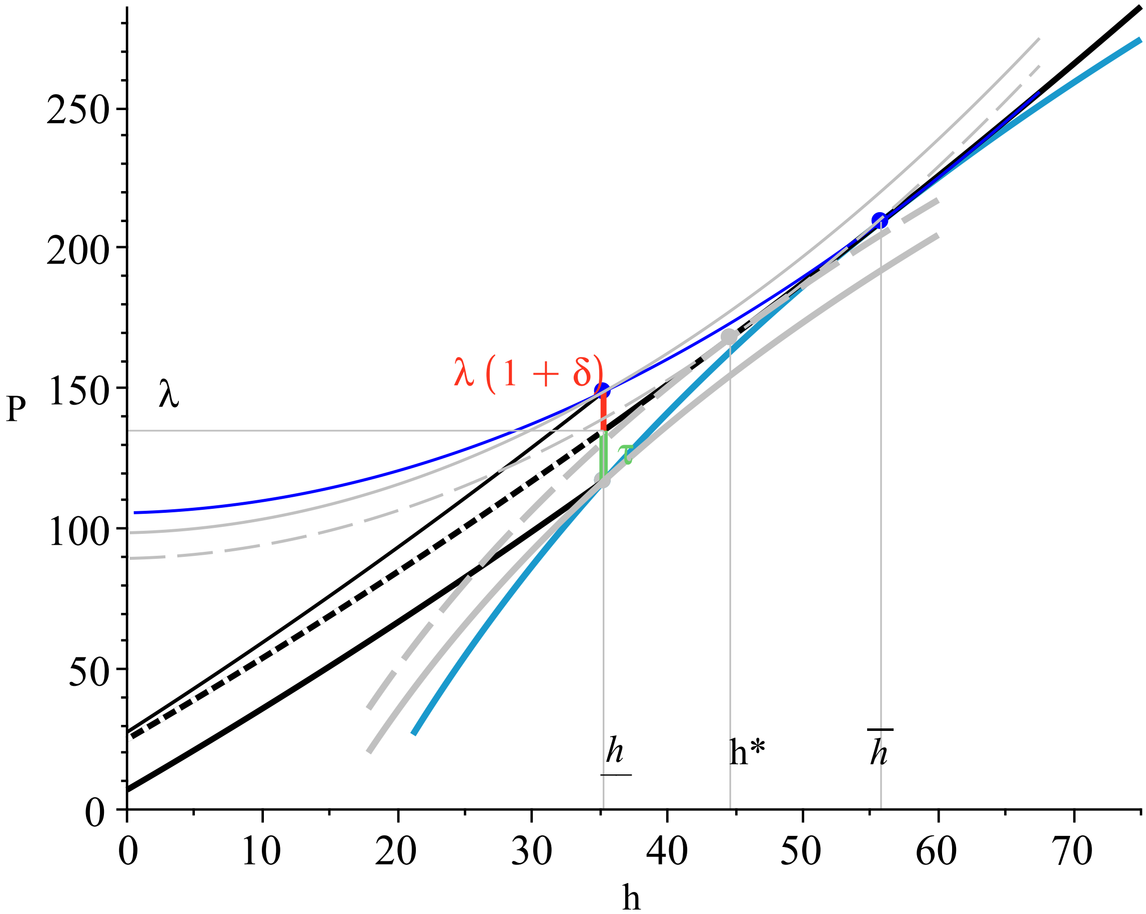
$$h^*\left(\overline{Y},\tau;\theta,\boldsymbol{\rho},\lambda\right)=\overline{h} \iff$$
$$U\left(\overline{Y}-P^\tau\left(\overline{h},\tau;\boldsymbol{\rho}\right),\overline{h};\theta\right)=U\left(\overline{Y}-P^\tau\left(\underline{h},\tau;\boldsymbol{\rho}\right),\underline{h}:\theta\right) \tag{26}$$

$$h^*\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho}\right)=\overline{h} \iff$$
$$\pi\left(Q(\underline{h};\alpha),\overline{A};\boldsymbol{\rho},\delta\right)=\pi\left(Q(\overline{h};\alpha),\overline{A};\boldsymbol{\rho},\delta\right) \tag{27}$$

these are agents indifferent between getting or not the policy incentives.

4. *Subsidized and Non-subsidized.* These are agents whose optimal choices are achieved when the *tangency conditions* are reached.

Figure 9: Marginally Subsidized and Marginal Buncher agents choices



Note: This figure shows the Optimal choices for the marginal buncher household and developer. This figures presents the intuition for the identification Idea. The gray offers and bid functions represent the indifference curve for the marginally subsidized aggents. These are the one that can increase there profits or utility by increasing reducing h to take advantage of the subsidy and tax incentives.

Figure explanation. Figure 4 shows an example of developers' and households' equilibrium choices. The price function is the envelope of the offer curves when developers produce their optimal unit size and the assigned number of units. The figure shows a representative marginal buncher households and developer. It also shows in gray marginally subsidized households and developers which are the agents that change their behaviour to take advantage of the subsidy. A developer type A_j matches with a household type Y_i in terms of their optimal choice of h when the dashed lines kissed. However this is not an equilibrium choice because both developers and households can be better off if they reduce size h. Figure 4a, shows the case of subsidized households and developers. Below $\bar{h}$, developers receive $P(1+\delta)$ and household pay $P+\tau$. Developers and households increase their utility and profits as a result. The marginal bunching agents are indifferent between getting the subsidy or not. The identification approach in this paper relies on these agents and therefore the main identification strategy is convey in figure 4. The idea is that the bunching in the observed equilibrium distribution allows me to recover $\overline{h}$. Therefore, I can observe two points,$\underline{h}$ and $\overline{h}$ in the same indifference and offer function and recover their shape. In the appendix 2 the figure 4 shows the examples of the optimal choices for other developer types.

Individual Level Supply and Demand

If $Y_i \in (\underline{Y}, \overline{Y})$, and $A_j \in (\underline{A}, \overline{A})$ households and developers pick $\underline{h}$, which is lower than their marginal willingness to pay but allows them to get the subsidy. When $Y_i \notin (\underline{Y}, \overline{Y})$ and $A_j \notin (\underline{A}, \overline{A})$ household choose h such that their marginal willingness to-pay for an additional unit is equal to the marginal implicit price. This happens when the bid and price functions are tangent. Therefore, the individual supply and demand functions are

$$h^{\mathrm{D}}(Y_i;\tau,\theta,\boldsymbol{\rho},\lambda) = \begin{cases} h^*(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda) & \text{if } Y_i \leq \underline{Y} \\ \underline{h} & \text{if } \underline{Y} < Y_i < \overline{Y} \\ h^*(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda) & \text{if } \overline{Y} \leq Y_i \end{cases} \tag{28}$$

$$h^{\mathrm{S}}\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho},\lambda\right) = \begin{cases} h^*\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho},\lambda\right) & \text{if } A_j \leq \underline{A} \\ \underline{h} & \text{if } \underline{A} < A_j < \overline{A} \\ h^*\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho},\lambda\right) & \text{if } \overline{A} \leq A_j \end{cases} \tag{29}$$

Productivity and Income mapping to housing size.

Because households only differ by income level Y_i, and under the assumption that $h^*(Y_i, \tau; \theta, \boldsymbol{\rho}, \lambda)$ is strictly monotone, it is possible to know the household income from the choice of housing satisfying the optimality conditions.[35]

$$Y_i = \tilde{Y}(h, \tau; \theta, \boldsymbol{\rho}, \lambda) = h^{*-1}(h_i, \tau; \theta, \boldsymbol{\rho}, \lambda) \tag{30}$$

Similarly, the productivity level determines the unit size.

$$A_j = \tilde{A}(h; \boldsymbol{\beta}, \delta, \boldsymbol{\rho}) = h^{*-1}\big(A_j, Q(h); \boldsymbol{\beta}, \delta, \boldsymbol{\rho}\big) \tag{31}$$

From distribution of Income and Productivity to a size distribution. The proportion of households choosing a housing unit of size h determines the market-level demand and supply densities. The income and productivity level uniquely determines the optimal level of housing. This monotonic relationship, and the change of variable formula, allows an expression for the distribution of h^* $f_h^*(h; \tau, \boldsymbol{\rho}, \theta, \lambda, \gamma)$m $g_{h^*}(h; \boldsymbol{\beta}, \delta, \boldsymbol{\rho})$, from the distribution of income f_Y, and productivity g_A

$$f_{h^*} = \begin{cases} f_Y\big(\tilde{Y}(h, \tau \neq 0; \theta, \boldsymbol{\rho}, \lambda); \gamma\big) \frac{\mathrm{d}}{\mathrm{d}h}\tilde{Y}(h, \tau \neq 0; \theta, \boldsymbol{\rho}, \lambda) & \text{if } h < \underline{h}(\boldsymbol{\rho}, \lambda) \\ f_Y\big(\tilde{Y}(h, \tau = 0; \theta, \boldsymbol{\rho}, \lambda); \gamma\big) \frac{\mathrm{d}}{\mathrm{d}h}\tilde{Y}(h, \tau = 0; \theta, \boldsymbol{\rho}, \lambda) & \text{if } \underline{h}(\boldsymbol{\rho}, \lambda) < h \end{cases} \tag{32}$$

$$g_{h^*} = \begin{cases} g_A\big(\tilde{A}(h; \boldsymbol{\beta}, \delta \neq 0, \boldsymbol{\rho})\big) \dfrac{\mathrm{d}\tilde{A}(h; \boldsymbol{\beta}, \delta \neq 0, \boldsymbol{\rho})}{\mathrm{d}h} & \text{if } h < \underline{h}(\boldsymbol{\rho}, \lambda) \\ g_A\big(\tilde{A}(h; \boldsymbol{\beta}, \delta = 0, \boldsymbol{\rho})\big) \dfrac{\mathrm{d}\tilde{A}(h; \boldsymbol{\beta}, \delta = 0, \boldsymbol{\rho})}{\mathrm{d}h} & \text{if } \underline{h}(\boldsymbol{\rho}, \lambda) < h \end{cases} \tag{33}$$

[35] Note that his mapping from housing consumption to income is a consequence of the assumption $\theta_i = \theta \, \forall i$. If I allow heterogeneity in θ, the same demand of housing h can come from different combinations of Y_i, θ_i.

Densities

These distribution h_{h^*} and g_{h^*} and the demand and supply function, $h^{\mathrm{D}}\left(Y_i;\tau,\theta,\boldsymbol{\rho},\lambda\right)$, allows as to get the market level demand density function, $D_h\left(h;\boldsymbol{\rho},\tau,\theta,\gamma,\lambda\right)$,

$$D_h = \begin{cases} f_{h^*}\left(h;\tau,\boldsymbol{\rho},\theta,\lambda,\gamma\right)\ \mathrm{d}h & \text{if } h < \underline{h}\left(\boldsymbol{\rho},\lambda\right) \\[2ex] f_{h^*}\left(\underline{h};\tau,\boldsymbol{\rho},\theta,\lambda,\gamma\right)\ \mathrm{d}h \\ \qquad\qquad + \int\limits_{\underline{h}}^{\overline{h}} f_{h^*}\left(h;\tau,\boldsymbol{\rho},\theta,\lambda,\gamma\right)\ \mathrm{d}h & \text{if } \underline{h}\left(\boldsymbol{\rho},\lambda\right) = h \\[2ex] 0 & \text{if } \underline{h}\left(\boldsymbol{\rho},\lambda\right) < h < \overline{h}\left(\tau,\theta,\boldsymbol{\rho},\lambda\right) \\[2ex] f_h^*\left(h;\tau,\boldsymbol{\rho},\theta,\lambda,\gamma\right)\ \mathrm{d}h & \text{if } \overline{h}\left(\tau,\theta,\boldsymbol{\rho},\lambda\right) \leq h \end{cases} \tag{34}$$

The demand of housing at the size limit $\underline{h}$ contains the demand of the *threshold maximizing households*, $f_{h^*}\left(\underline{h};\tau,\boldsymbol{\rho},\theta,\gamma\right)$, and *the marginally subsidize households* $\int\limits_{\underline{h}}^{\overline{h}} f_{h^*}\left(h;\tau,\boldsymbol{\rho},\theta,\lambda,\gamma\right)\ \mathrm{d}h$. Finally there is no demand for housing units with $h \in \left(\underline{h},\overline{h}\right)$.

Developers. This distribution and the unit supply function, $Q\left(h;\alpha\right)$ allows to get the market level supply density function, $S_h\left(h,\boldsymbol{\beta},\delta,\boldsymbol{\rho}\right)$.

$$S_h = \begin{cases} g_{h^*}\left(h;\boldsymbol{\beta},\delta,\boldsymbol{\rho}\right)\cdot Q\left(h;\alpha\right) & \text{if } h < \underline{h}\left(\boldsymbol{\rho},\lambda\right) \\[2ex] g_{h^*}\left(h;\boldsymbol{\beta},\delta,\boldsymbol{\rho}\right)\cdot Q\left(h;\alpha\right) \\ \qquad\qquad + \int\limits_{\underline{h}}^{\overline{h}} g_{h^*}\left(h;\boldsymbol{\beta},\delta,\boldsymbol{\rho}\right)\ \mathrm{d}h\cdot Q\left(h;\alpha\right) & \text{if } \underline{h}\left(\boldsymbol{\rho},\lambda\right) = h \\[2ex] 0 & \text{if } \underline{h}\left(\boldsymbol{\rho},\lambda\right) < h < \overline{h}\left(\tau,\theta,\boldsymbol{\rho},\lambda\right) \\[2ex] g_{h^*}\left(h;\boldsymbol{\beta},\delta,\boldsymbol{\rho}\right)\ \mathrm{d}h\cdot Q\left(h;\alpha\right)\left(h\right) & \text{if } \overline{h}\left(\tau,\theta,\boldsymbol{\rho},\lambda\right) \leq h \end{cases} \tag{35}$$

D. Market Equilibrium

The housing market achieves an equilibrium E when market level demand and supply are the same for all values of h at a given price scheme $P(h; \boldsymbol{\rho})$

$$E = \left\{ P(h; \boldsymbol{\rho}) \in \mathcal{P} : D(h; \tau, \theta, \boldsymbol{\rho}, \gamma, \lambda) = S\left(h; A_j, \boldsymbol{\rho}, \boldsymbol{\phi}\right) \forall h \in \mathcal{H} \right\} \tag{36}$$

where, $\mathcal{P}$ is the space of all price functions and $\mathcal{H}$ is the space of all possible housing units. The Price scheme satisfies the equation 14, and $S\left(h; A_j, \boldsymbol{\rho}, \boldsymbol{\phi}\right)$ is the market supply density. The equilibrium price function must guarantee that the number of units supplied and demanded coincide.

Existence of hedonic equilibrium. The existence of an hedonic equilibrium has received comparatively less attention than the identification of this type of model. S. Rosen (1974) and Epple (1987), show that under some specified utility function, cost functions, and distributions for the unobserved heterogeneity, a closed-form solution for the equilibrium price function exist. Heckman et al. (2010) explicitly describes how the equilibrium price function depends on on the distributions of observable characteristics of firms and workers.Ekeland (2010) shows an existence proof and provides a particular example for an equilibrium. Moreover, (Bajari & Benkard, 2005) prove that, in equilibrium, the price of a differentiated product will be a function of its characteristics if utility is continuously differentiable, monotonic in numeraire, and Lipschitz continuous. For the particular model presented in this paper, particular, more restrictive functional forms allow to get a closed form solution.[36]

Graphical representation

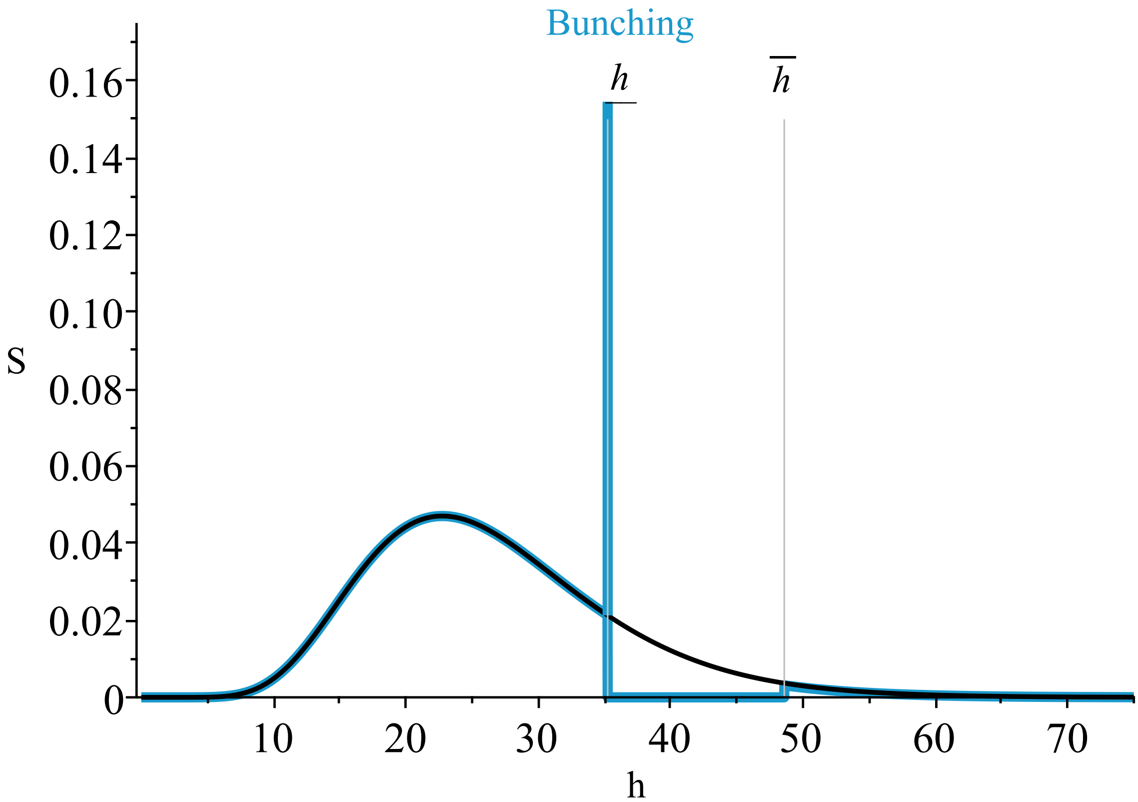
Figure 10 shows the product space or developer density, and figure 10 the exogenous unit supply function. Figure 10a shows an example of the equilibrium density when f_Y follows a log-normal distribution. The equilibrium price makes the product of the functions in figures 10 and 10 to match the demand density. Appendix figure 3 shows the price function and densities that correspond to the observed equilibrium densities of the standardized unit by size. Additionally, appendix figure 1 represents the empirical analog of the figure 10.The observed density function suggests that the market equilibrium has a discontinuous density and that this stylized model can explain the equilibrium outcomes presented in figures 8. Because I standardized all

[36] A particular example is available upon request.

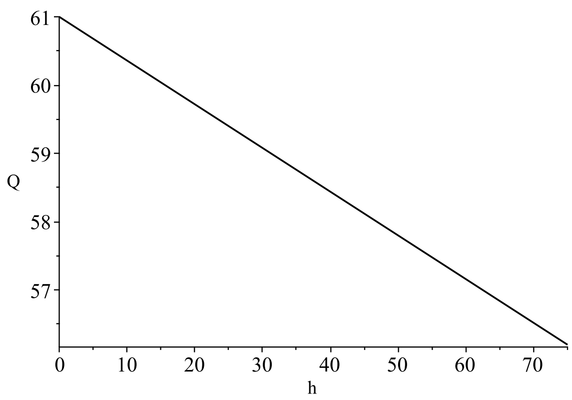
housing units, the differences in housing characteristics disappear and standardized units only vary along a price and size dimension.

Figure 10: Equilibrium Density, developer's choice density and unit supply function

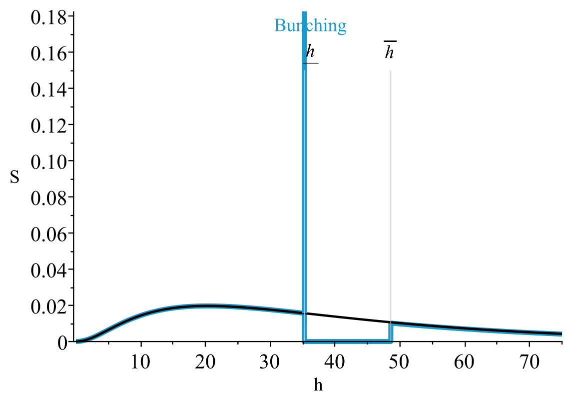
a. $Y \sim$ log normal Y



b. Unit supply function $Q_j = \alpha_0 + \alpha_1 \cdot h_j$



c. Density Function $g_h(h)$



NOTE: This figure shows the equilibrium market share or distribution of units by standard unit size for a given income density f_y following a log-normal. The empirical analogs of this figure, are in figure 8. The panels and show the share of developers choosing to build at each unit size and the unit supply function and the unit supply function. Appendix figure 1 and figure and numbers in table 2 are the empirical analogs for these figures.

Missing mass between $\underline{h}$ and $\overline{h}$

The model predicts that no housing units should be between $\underline{h}$ and $\overline{h}$. However, in my empirical estimates, I only observe a partial missing mass in the distribution. This partial missing mass is common in bunching analysis using notches (Best et al., 2019; Kleven & Waseem, 2013). These is usually attributed to at least two potential factors, optimization, friction or heterogeneity on the the behavioural parameters θ. Some households may not be aware of the subsidies or the application costs are too high. In my setting, there is a limited number of subsidies and not all households that qualify actually get it. Moreover, it could be the case that households that are eligible do not really see its benefits. Buying and living in a low-cost housing unit could create stigma and households may have a big dis-utility related to that.

Another possible explanation is that there is heterogeneity across preferences. In this case θ for example may differ across cities. Best et al. (2019) suggest that the behavioural response can be interpreted as the average marginal response in such cases.

V. Identification

The behavioural parameters to estimate are θ, β, which describe the curvature of the bid and offer curves. This section explains the identification and the estimation.

A. Marginal buncher

Marginal Buncher Indifference conditions. The identification argument in this paper follows the approach used by Best et al. (2019) and more generally the one suggested by Bertanha, McCallum, and Seegert (2021) and Blomquist, Newey, Kumar, and Liang (2021). The idea is that the existence of the marginal buncher allows to observe two points in the same bid and offer function.[37] Following the hedonic literature, the estimation approach follows a two-step procedure. In the first step, I use the analysis in sections 2 and 3, to get the hedonic price function, the notch, and the behavioural responses. In the second step, I use the marginal bunching condition to solve for the two parameters of interest. From equations 26 and 27, I recover the

[37] Best et al. (2019) proposition 1 and Bertanha et al. (2021) Theorem 1 both prove identification using the same identification idea in this paper. The identification in my setting follow the same principle conditional on getting consistent parameters in the first step.

marginal buncher household's and developer's conditions:

$$V_d\left(\theta|\underline{h},\overline{h},\boldsymbol{\rho},\tau,\overline{Y}\right)=U\left(\overline{Y}-P\left(\overline{h};\boldsymbol{\rho}\right),\overline{h};\theta\right)-U\left(\overline{Y}-P^{\tau}\left(\underline{h};\boldsymbol{\rho},\tau\right),\underline{h};\theta\right)=0 \tag{37}$$

$$V_s\left(\beta|\underline{h},\overline{h},\boldsymbol{\rho},\boldsymbol{\alpha},\delta,\overline{A}\right)=\pi\left(Q(\overline{h};\alpha),\overline{A};P\left(\overline{h};\boldsymbol{\rho}\right);\beta\right)-\pi\left(Q(\underline{h};\alpha),\overline{A};P^{\delta}\left(\underline{h};\boldsymbol{\rho},\delta\right);\beta\right)=0 \tag{38}$$

The parameters, θ and β are estimated as the solution of these two equations. Given estimates of $\overline{h},\underline{h},P\left(\overline{h};\rho\right),\tau,\delta,\alpha$ and expressions for $\overline{Y}$ and $\overline{A}$, β and θ are the only unknowns in equations 37 and 38. I do not observe $\overline{Y}$ and $\overline{A}$, but I use the optimality conditions in equations 29, 25 to express $\overline{Y}$ and $\overline{A}$ in terms of observable characteristics $\overline{h},\underline{h},P\left(\overline{h};\rho\right),\tau,\delta$, and α.

Bertanha et al. (2021) describes the identification assumptions under which we can recover the structural parameters from observed bunching. They argue that notches allow for the identification of elasticities while kinks need additional assumptions about the unobserved heterogeneity. Blomquist et al. (2021) show the conditions under which elasticities can be identified under notches and kinks. They illustrate their approach using Saez (2010) setting.[38] In contrast to Blomquist et al. (2021) who assume the pdf of heterogeneity is monotone, Bertanha et al. (2021) derive partial identification bounds by assuming the pdf has a bounded slope. Using censored regression models, covariates, and semi-parametric assumptions on the distribution of heterogeneity, they provide point estimation for kink points.

B. Estimation

Table 4 shows the functional forms I am using to recover the behavioural parameters θ and β. The estimation approach follows a two-step procedure. The first step relies on the estimated parameters presented in the first part of the paper, $\overline{h},\underline{h},P\left(\overline{h};\rho\right),\tau,\delta,\alpha$. The second step uses the estimates from these parameters and the marginal buncher condition to recover the behavioural parameters describing the utility and cost functions, β and θ.

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Table 4: Functional form and identification equations.

Marginal Buncher Condition	
Household	$V_D = U\left(\overline{Y} - P\left(\overline{h}\right), \overline{h}; \theta\right) - U\left(\overline{Y} - P^{\tau}\left(\underline{h}\right), \underline{h}; \theta\right) = 0$
Developer	$V_S = \pi\left(Q(\overline{h}), \overline{A}, P\left(\overline{h}\right); \boldsymbol{\beta}\right) - \pi\left(Q(\underline{h}), \overline{A}; P^{\delta}\left(\underline{h}\right); \boldsymbol{\beta}\right) = 0$
Optimality Conditions	
Income	$\overline{Y} = \tilde{Y}\left(\overline{h}; \theta, P(h), \lambda\right)$
Productivity	$\overline{A} = \tilde{A}\left(\overline{h}; \boldsymbol{\beta}, P(h), \lambda\right)$
Functional Forms	
Implicit Price	$P = \rho_0 + \rho_1 \cdot h + \rho_2 \cdot h^2$
Utility	$U = \left[\frac{1}{2} \cdot C^{\theta} + \frac{1}{2} \cdot h^{\theta}\right]^{\frac{1}{\theta}}$
Unit Supply	$Q = \alpha_0 + \alpha_1 h$
Cost	$B = A_j \cdot Q \cdot h^{\boldsymbol{\beta}}$

NOTE: This Table summarizes the functional forms used for the estimation of $\boldsymbol{\beta}$ and θ. The functional forms for the optimality conditions are in the appendix 2.

Observed and Unobserved Objects

The observable objects are developer density, g_h and equilibrium distribution of housing size f_h. Note that the equilibrium distribution f_h is g_h multiplied by the number of units built $Q(h)$ which is observable. This allows me to estimate $Q(h|X)$ and get α_0 and α_1. The equilibrium price P and housing characteristics X_{lt} allows me to estimate the implicit price function for housing characteristics, $P\,(h|X)$. With this, I recover the parameters ρ_0, ρ_1, ρ_2 and I use the implied substitution pattern to transform every house into a standard housing unit of size h. The policy parameters, $\tau = \tau^m + \tau^r$, δ corresponds to the average subsidy τ and refund rate δ.

My data does not have information on income Y or productivity A and the functional forms forms for $P(h)$, $U(.)$, $B(.)$, $Q(.)$ are unknown.The estimation approach relies on specified functional forms for utility, unit supply, cost and implicit price functions. Table 4 shows the particular functional and main identification conditions I use to recover the structural parameters.

First Step: Parameter Estimates

The reduced-form evidence and analysis from section ̊corresponds to the first step. In particular, The policy parameters τ,δ, correspond to the notches presented in figure 2.3 and table 1. The implicit price function and implied size threshold are recovered from the hedonic price function presented in figure 6. The estimates from the hedonic price function allow me to get the empirical content for the standardized housing size h. Using the estimates from the hedonic price function, each housing unit is transformed into a standard unit of size h $\underline{h}$, $P\left(\overline{h};\rho\right)$ The bunching estimates allow me to recover $\overline{h}$ and the relationship between size and number of units allows me to recover the parameters α_0 and α_1.

Second Step: Estimation of θ, and β

For given functional forms and estimates of the observable parameters describe in section 5.2, I can solve for θ and β. Note that the marginal buncher functions are highly nonlinear and it is not possible to get a close-form solution. I use numerical methods to find the values of θ and β. I present estimates separately for each subperiod with specific subsidy schemes.

VI. Structural Estimates and Welfare

The main objective of the paper is to evaluate how this subsidy affects households and developers. The first part of the paper presents compelling empirical evidence suggesting that the subsidy is affecting the housing market equilibrium. Section 4 introduced an economic model to rationalize such responses. In this section, I use the economic model and the estimated parameters to illustrate the incidence of this policy. The economic model allows me to quantify the gains and losses induced by the subsidy and evaluate its relative importance.

Behavioural parameter estimates

Table 5 summarizes the results from the first step and presents the structural parameters recovered in the second step for the 4 different periods. The parameter $\sigma = 1/(1-\theta)$ is the elasticity of substitution for the CES utility function. It represents how does the relative consumption of housing varies when the relative price changes.

Households' parameters. The estimate for the elasticity of substitution between housing and consumption of other goods is around 0.9. It is slightly lower in the first period and higher in the second period. But the fact that the estimated parameters are similar across years is reassuring, considering that these are economic fundamentals and therefore very unlikely to fluctuate over time.

An elasticity of 1 corresponds to a Cobb Douglas elasticity, therefore my estimates suggest that a Cobb Douglas Utility function would not be a bad representation. A negative value of θ which corresponds to an elasticity of substitution σ lower than one, means that housing and other goods are gross substitutes. If θ is positive, the elasticity of substitution is higher than one, and housing and consumption of other goods would be gross substitutes.

Table 5: Structural and first stage parameters.

	06-08	09-11	12-15	16-18
Price Function				
ρ_0	17.0	-300.0	-243.5	-240.6
ρ_1	2.70	4.75	4.48	4.66
ρ_2	0.90	0.32	0.73	0.60
Policy Parameters				
τ	18.0	25.9	29.5	32.6
Bunchers Interval				
$\overline{h}$	40	53	45	49
$\underline{h}$	29.8	39.4	33.0	36.0
Unit Supply Function				
α_0	70.5	12.7	81.1	33.3
α_1	-0.068	-0.020	-0.020	-0.042
Structural Parameters				
β	2.53	1.67	1.77	1.70
σ	0.85	0.97	0.90	0.90
θ	-0.17	-0.028	-0.11	-0.11

NOTE: This Table summarizes the relevant estimates from the first part of the paper and are part of the estimation. In particular, the hedonic price functions, the notch τ, the behavioural response $\underline{h}$, the policy threshold $\underline{h}$, i.e., the maximum size of a standard unit that gets the subsidy and the parameters of the unit supply function α_1 and α_0. The elasticity of substitution implied by the CES utility is $\sigma = 1/(1-\theta)$.

Bayer, Ferreira, and McMillan (2007) is a representative approach that integrates the hedonic insights into a discrete choice framework. As pointed out by Yinger (2015), their approach implicitly assumes a linear utility function, which violates the strict quasi-concavity postulate. In other approaches in urban economics literature, the utility function is assumed to be Cobb Douglas. In my setting, I allow for a less restrictive functional form, but my estimates suggest that the a Cobb-Douglas utility function would be a close approximation.

Developers' parameters. On the developer side, the estimated parameter β, changes as the new subsidies are introduced. In the first period beta is 2.53 , this decreases to around 1.7 in the following periods. This change means that the costs of building bigger houses decreased over time.

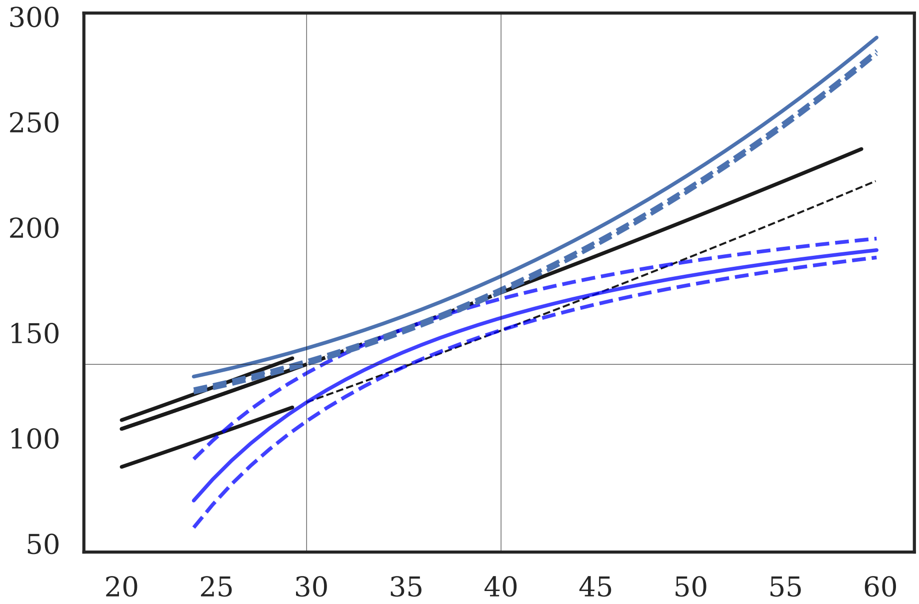
Benefits and efficiency losses on the demand side

To evaluate the benefits of the subsidy, I focus on the effect on marginally subsidized households. The price limit creates efficiency losses if, like I am assuming, the response on the supply side is a reduction in price and housing size. Figure 11 Illustrates how a representative marginally subsidized household benefits from the subsidy. By reducing its household consumption and getting the subsidy, the utility increase. The indifference curve moves from the dashed line to the solid line. Without the existence of the price limit and if the marginally subsidized household gets the subsidy without reducing its consumption, households can be better off.

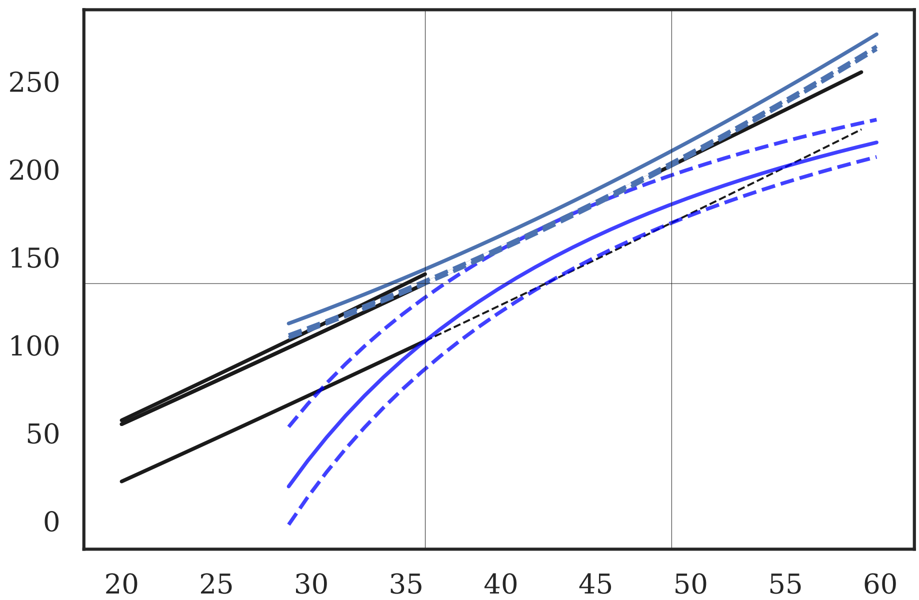
Welfare if only price changes. This paper interprets the bunching as changes in housing characteristics. However, I acknowledge that it could be the case that there are only changes in housing prices without adjustments in characteristics. If this is the case, the welfare analysis is very different. What I call a welfare loss would be in contrast a welfare increase induced by the price limit. Having conclusive evidence on whether housing characteristics change or not, it is crucial to determine welfare benefits. However, the framework presented in this paper can interpret the two scenarios.

Figure 11: Representation of the marginally subsidized households and developers

06-08



16-18



Note: This figure uses the estimated parameters presented in figure 5 and creates the empirical analog of figure 4 for the marginally subsidized household and developer. This figure represents the equilibrium choices and bid and offer functions estimated at the beginning and at the end of the study period. This figure motivates the counterfactual exercises presented in Table 11

Table 6: Evaluating the effects of the policy using the estimated parameters

	Households			
	06-08	09-11	12-15	16-18
$\underline{Y}$	215.7	324.0	275.6	291.5
Y_*	248.7	392.5	333.7	355.6
$\overline{Y}$	282.8	461.7	393.2	421.1
$U\left(\underline{Y} - P\left(\underline{h}\right), \underline{h}\right)$	47.9	85.6	66.3	72.9
$U\left(\underline{Y} - P^{\tau}\left(\underline{h}\right), \underline{h}\right)$	52.5	91.2	72.4	79.5
$U\left(Y_* - P\left(h^*\right), h^*\right)$	56.8	100.7	78.9	86.6
$U\left(Y_* - P^{\tau}\left(\underline{h}\right), \underline{h}\right)$	59.6	104.3	82.7	90.7
$U\left(Y_* - P^{\tau}\left(h^*\right), h^*\right)$	61.4	106.3	84.9	93.2
$U\left(\overline{Y} - P\left(\overline{h}\right), \overline{h}\right)$	65.9	116.0	91.7	100.5
	Developers			
	06-08	09-11	12-15	16-18
$\underline{A}$	0.0068	0.26	0.19	0.25
A_*	0.0054	0.23	0.17	0.22
$\overline{A}$	0.0045	0.21	0.15	0.20
$MgC\left(\underline{h}, Q\left(\underline{h}\right), \underline{A}\right)$	214.4	59.5	398.2	160.7
$MgC\left(\underline{h}, Q\left(\underline{h}\right), A_*\right)$	219.0	59.0	404.4	161.2
$MgC\left(h^*, Q\left(h^*\right), A_*\right)$	172.4	53.7	356.0	144.9
$MgC\left(\overline{h}, Q\left(\overline{h}\right), \overline{A}\right)$	223.4	58.6	410.6	161.7
$\pi\left(Q\left(\underline{h}\right), \underline{A}; P\left(\underline{h}\right)\right)$	6725.5	205.8	3449.4	881.6
$\pi\left(Q\left(\underline{h}\right), A_*; P^{\delta}\left(\underline{h}\right)\right)$	7588.2	406.1	4668.9	1388.9
$\pi\left(Q\left(\underline{h}\right), A_*; P\left(\underline{h}\right)\right)$	7218.6	341.6	4234.4	1217.2
$\pi\left(Q\left(h^*\right), A_*; P^{\delta}\left(h^*\right)\right)$	7740.0	439.8	4889.1	1478.6
$\pi\left(Q\left(h^*\right), A_*; P\left(h^*\right)\right)$	7326.4	359.9	4359.1	1266.4
$\pi\left(Q\left(\overline{h}\right), \overline{A}; P\left(\overline{h}\right)\right)$	7930.5	512.2	5262.2	1646.0

NOTE: This table shows estimates of the implied income Y and productivity level of three representative households and developers. The threshold optimizer, with income $\underline{Y}$ and $\underline{A}$, a representative marginally subsidized household with income Y_* and A_*, and the marginal buncher, with income $\overline{Y}$ and $\overline{A}$. For households, the table shows different utility levels, $U\left(Y_i - P(h_i), h_i\right)$ evaluated at different choices of h_i, paying the market price $P(h_i)$ or receiving the subsidy $P^{\tau}(h_i)$. For developers, the table shows the Marginal Costs $MgC(h, Q(h), A)$ and Profits $\pi\left(Q\left(h_j\right), A_j; P\left(h_j\right)\right)$, evaluated at different levels of h_j getting the sales price only $P(h_j)$ or getting the tax incentives too, $P^{\delta}(h_i)$.

Estimates. Table 6 uses the estimated parameters to evaluate the utility levels at the observed choices and the relevant counterfactual scenarios. In particular the table shows the implied income Y for the threshold optimizer household, a representative marginally subsidized household, and the marginal buncher. It evaluates the utility of the representative marginally subsidized household in 3 points. The counterfactual scenarios where she consumes a housing unit with size satisfying the *tangency conditions*, h^* at the observed price scheme $P(h)$, the utility for the observed consumption. and the utility if she gets the subsidy but does not have to reduce housing consumption to get it.

How important are the supply subsidies?

It is important to know how important the supply subsidies are to maintain the equilibrium in this market. What would happen if there were not supply subsidies? Figure, 11 illustrates how tax refunds increase developers profits, when they reduce the unit size to meet the increase in demand at the price threshold. If they do not get that incentive, they would have to reduce their profits to stay in the market.

Estimates. Table 6 shows estimates of marginal costs and profits using the estimated parameters and economic model. As with the demand side I show marginal cost estimates for three relevant developer types.

Context and relevance. An argument to support housing subsidies is that by giving a subsidy to buy new housing, developers also benefit.[39] Moreover this is an important policy debate, in Colombia the construction sector argues that eliminating the housing subsidies will create a rationing problem.[40]

Differences from a standard model with homogeneous agents and housing units.

In this subsection I represent the equilibrium choices graphically in and alternative way to show how the economic analysis differs from a basic framework, rejected by the data, assuming homogeneous goods and agents. To illustrate this, figure 12

[39] For example "Another explanation for the existence of low-income housing subsidies is political. An in-kind subsidy tends to help not only the beneficiary, but also the producers of the favored commodity. Thus, a transfer program that increases the demand for housing will tend to benefit the building industry, which will then lend its support to a coalition in favor of the program. As indicated in Section 4.1 below, housing programs for the poor have focused on the construction of new units, thus benefit the housing industry rather directly." H. S. Rosen (1985)

[40] *If these items are repealed, in Valle del Cauca we would go from having an offer of SH and sales of 23,000 homes, average year, to one of sales of 4,600 homes* El Tiempo (2021)

shows an alternative graphical representation for the equilibrium choices. It show the demand and supply functions in terms of the marginal price, or MWTP. If there was only one type of housing and homogeneous agents, a single point where the demand and supply match will characterize the equilibrium. The welfare evaluation of the subsidy will be straightforward. Under the case studied here, multiple goods are treated in equilibrium. However, there is an additional difference caveat, if developers all have the same cost function, a single function will characterise the supply side, which in this case will be the black line. In contrast, with heterogeneous developers, the black line is the marginal equilibrium price where different developers and households match. The effect of the subsidies on developers will be very different in the two scenarios. More over, if we do not allow for nonlinearities in the implicit price function, the black line will be constant and will imply a perfectly elastic supply. In figure 12 the different lines show three developers and household types. This figure makes it clear how to do an evaluation of the effects of the subsidies, it is not enough to recover the shape of the implicit price function.We need the demand and supply curves, without estimates of the primitives, it is impossible to do nonmarginal welfare analysis. In this paper, I recover them using the marginal buncher condition.

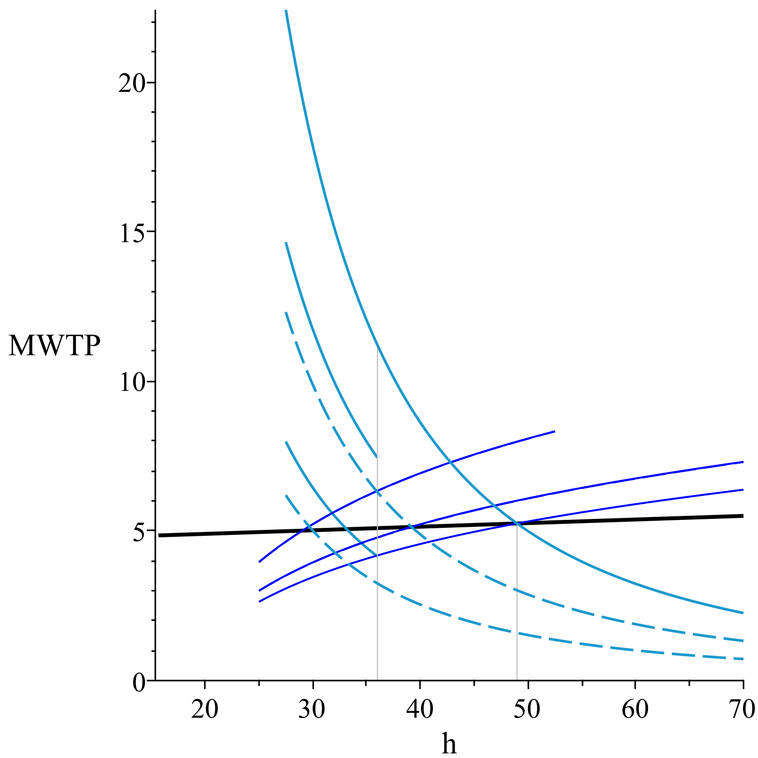


Figure 12: Demand, supply function and marginal equilibrium implicit price

VII. Conclusions

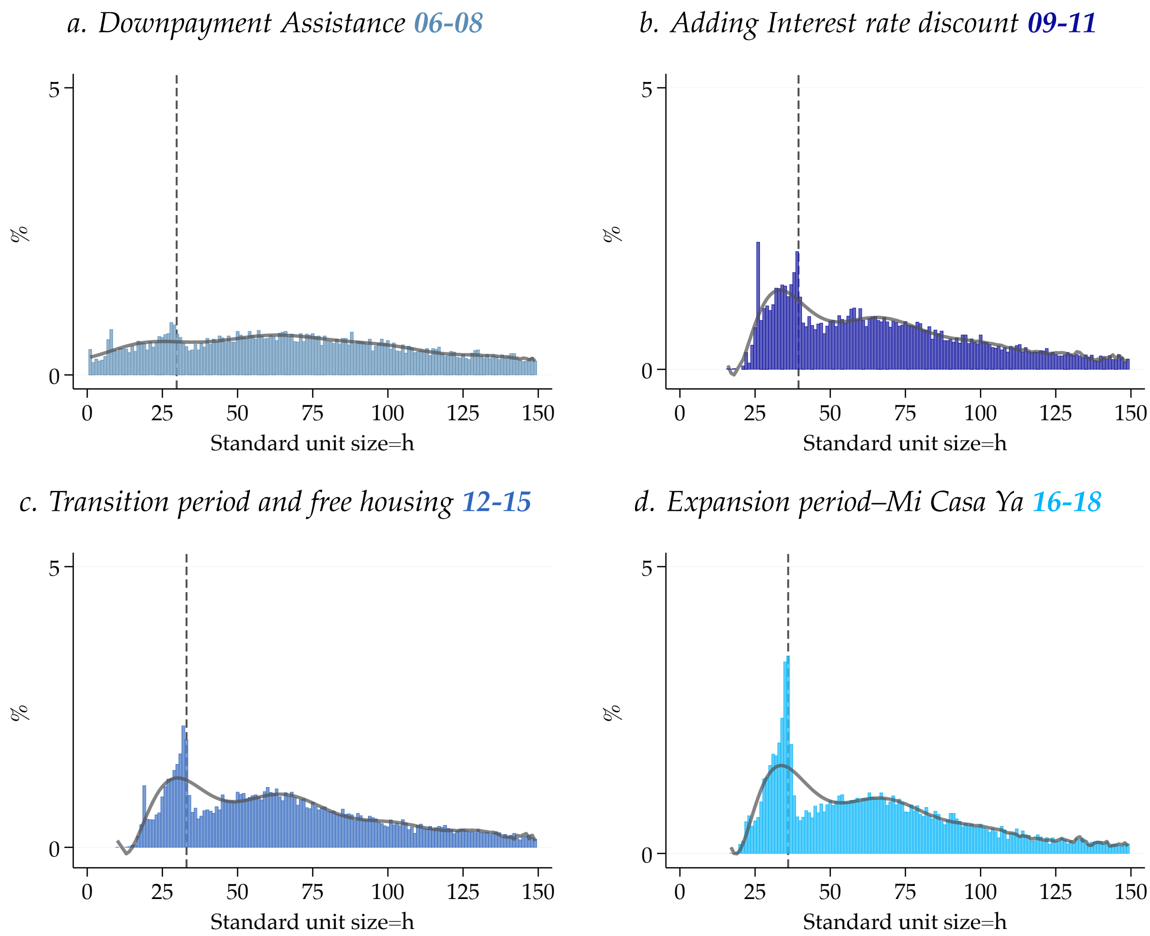
Main takeaways

Open questions and remaining challenges

- How does the new housing affect the housing market? (i.e. Does it affect the prices of the existing housing stock?)
- employment effects and stimulus effect.
- What is the role of banks
- What are the difference between interest rate subsidy and mortgage deduction subsidy. Does it matter.

I. Additional Bunching Results

Figure A- 1: Share of developers by unit size of the Standardized housing

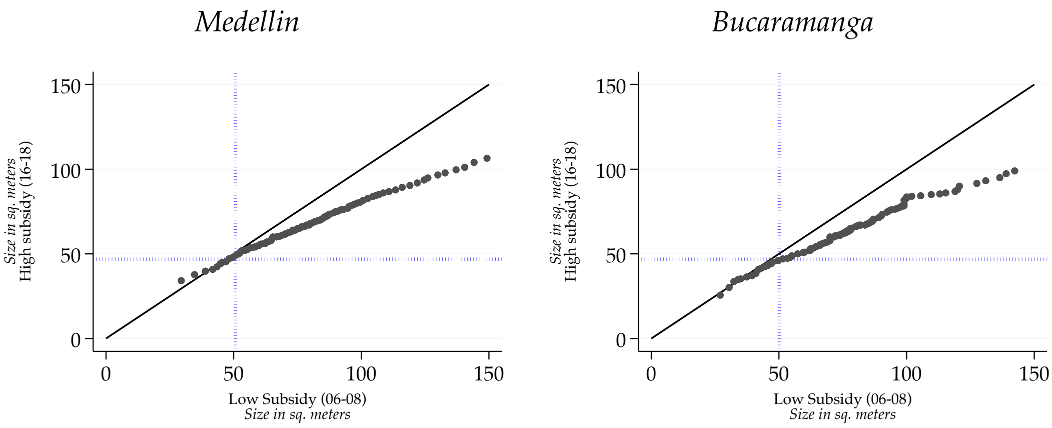


Note:

Table A- 1: Behavioral Responses Estimates′

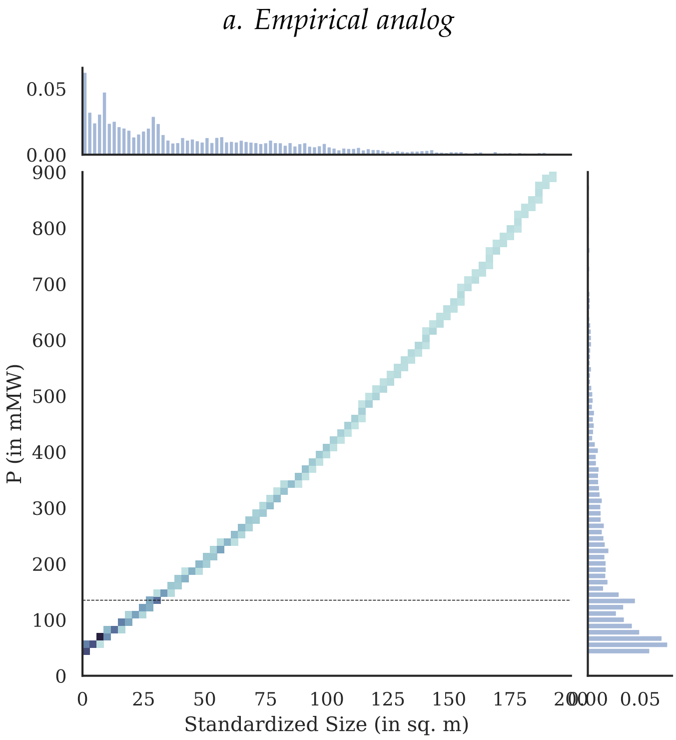
	06-08	09-11	12-15	16-18
$\int_{h_{min}}^{\underline{h}^{-}} T(h)\mathrm{d}h$	0.75	0.61	1.81	3.61
$\hat{T}\,(\underline{h})$	0.29	0.85	0.72	1.94
$\int_{h_{min}}^{\underline{h}} T(h)\mathrm{d}h$	1.05	1.46	2.53	5.56
$\int_{\underline{h}}^{\overline{h}} T(h)\mathrm{d}h$	-0.40	-1.79	-3.68	-4.48
$g_{h^0}\,(\underline{h})$	0.57	1.01	1.01	1.18
h_{min}	24	37	27	30
$\underline{h}$	29.8	39.4	33.0	36.0
$\overline{h}$	40	51	45	50

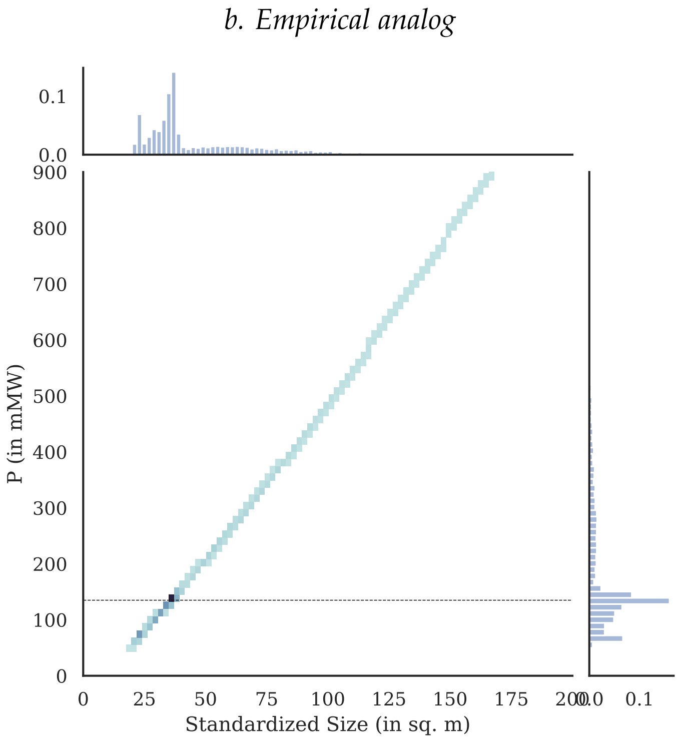
Figure A- 2: Q-Q plots for housing size. Low vs. high subsidy periods



Empirical analogs

Figure A- 3: Observed Equilibrium densities and hedonic price 06-08





II. Model Appendix:

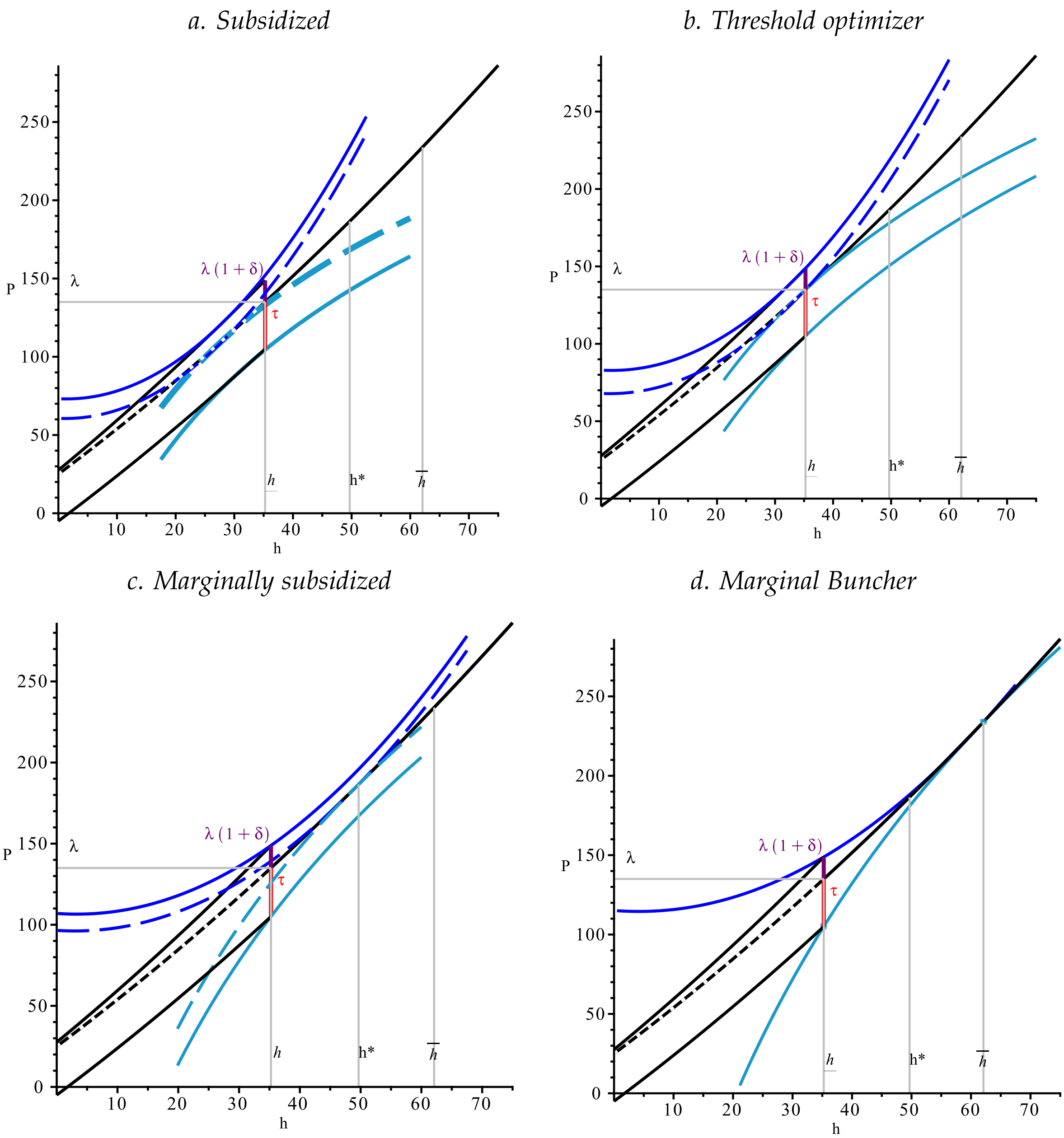


Figure A- 4: Graphical representation of equilibrium choices

The offer function functional form is: $\varphi_j^S = \frac{\bar{\pi}_j \cdot h^2}{\beta_1} + A_j$. This results from a cost function $C\left(Q(h), A_j\right) = A_j * Q(h)$, and $Q(h) = \frac{\alpha}{h^2}$

III. Colombian Housing Policy: Additional Details

A. Minimum wage and Inflation

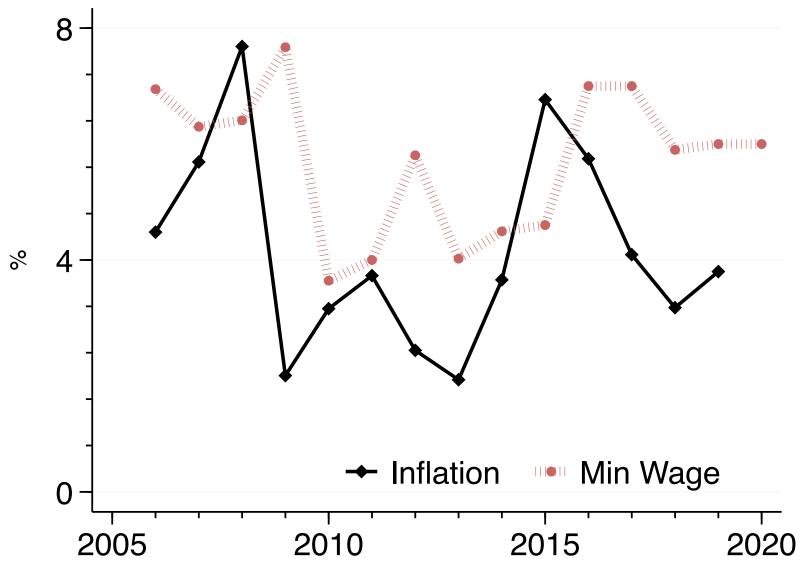


Figure A- 5: Inflation and Minimum wage overtime

B. Details About Subsidies

Down-Payment Subsidy. The down payment subsidy was introduced at the beginning of the nineties and is available to formal employees who contribute to the family compensation funds.[41] The **gray blue** area in Figure 1 shows the number of subsidies and total government expenditure from 2006 until 2019. The number of downpayment subsidies to formal employees was more or less stable during the study period, but the government spending increased in 2015 due to an increase in the size of the subsidy. Only formal households earning below 4 times the minimum wage are eligible for the subsidy, and the subsidy can only be used to buy a social housing unit.

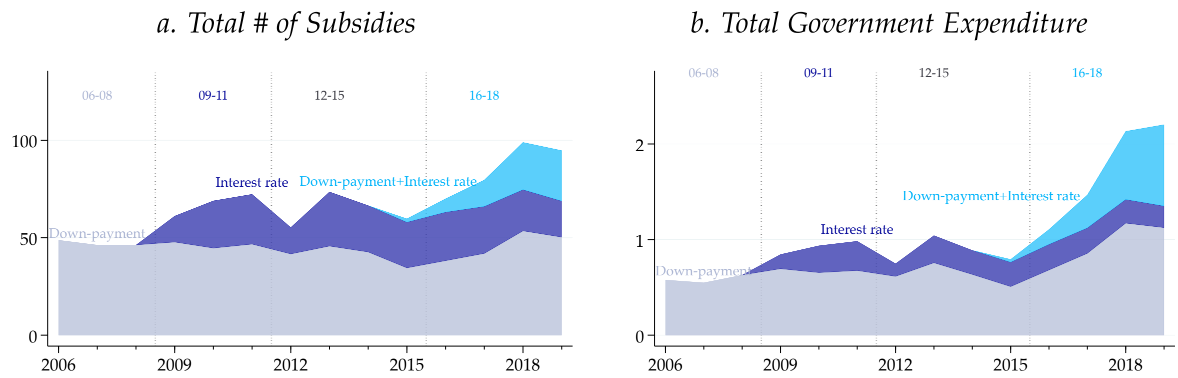
Interest rate subsidy. In 2009, the government introduced a program to subsidize mortgages' interest rates. This program called *FRECH*, started as a program to incentivize economic growth after the crisis, but became a permanent policy. In

[41] The subsidy is call *subsidio familiar de vivienda (SFV)* and they the is administered by the family compensation funds are and was introduced in the Law 3 of 1991. The definition of formal employee in this case is to contribute to social insurance and the compensation family fund.

contrast to the downpayment subsidies, interest rate subsidies were also available to households buying housing units above the $135\times$ mMW threshold. However, the subsidy is bigger if the households buy a social housing unit, i.e., the price is less than $135 \times$ mMW. If a household receives the subsidy, the government pays the bank the corresponding amount during the first seven years of the loan. Three different schemes existed during my study period, but in all schemes there is a discontinuity in the subsidy at the cutoff defining social housing. The **dark blue** area in Figure 1 shows the number of subsidies and total government expenditure from 2011 until 2019. The subsidies were more or less stable over time; around 20 thousand households received this subsidy. This subsidy represents lower government expenditure and expenditure has slightly decreased overtime partly due to lower interest rates. Subsection 3.3 in the appendix presents more details about this subsidy.

The subsidy expansion–Mi casa ya. In 2015, the government doubled the effort and introduced a new program *Mi casa ya*, (my house now). Before this program was introduced, the down payment subsidy was only available to formal employees-contributing to the family compensation funds.[42] This program extended the coverage of the downpayment to noncontributing households and households participating in this program get the downpayment subsidy and interest rate subsidy automatically with a single application. The **light blue** area in Figure 1 shows the number of subsidies and government expenditure, which is the sum of the downpayment and the total expenditures with the interest rate discount. The figure shows that the increase in the number of subsidies and government expenditure that started in 2015 is mainly driven by the introduction of this program and the increase in the down payment subsidy to formal employees.

[42]In theory informal household could get access to housing subsidies. However, *fonvivienda*, the institution in charge of these subsidies, assigned mostly to vulnerable populations. The vulnerable populations are displaced by armed conflict and affected by natural disasters. I include the equivalent plots for those subsidies in the appendix 3.



Demand Subsidies Overtime

NOTE: Source: Minvivienda, FRECH

Supply Subsidy–VAT tax refund. A couple of years after the demand subsidies were introduced, and to encourage developers to build social housing, the government introduced a VAT tax refund. Developers get up to 4 percent of the sale price of each unit in the refund of taxes paid in construction materials.[43] I include this subsidy in the analysis. Accounting for this subsidy introduces nonlinear incentives on the supply side.

Other Subsidies. The Colombian housing policy includes other subsidies excluded from the main analysis of this paper.[44] These are mainly subsidies to disadvantaged populations. These subsidies exist to follow a constitutional mandate of providing housing to people affected by forced displacement and environmental disasters. They are for cheaper housing units and households in extreme poverty. These subsidies can be used to buy *priority social housing*, which are housing units with a market price of $70 \times mMW$ or less. The approach of using subsidies as incentives to promote construction and purchases of housing units was mostly ineffective to provide this type of housing. As a result, in 2014, a program to build 100 thousand free housing units was launched. The goal was to satisfy the constitutional mandate and provide housing to the disadvantaged population neglected by the previous policy approaches.A. G. Gilbert (2014) describes this program, *100 mil viviendas gratis*, and evaluates its potential effectiveness. Camacho, Caputo, and Sanchez (2020) study the effect of this conditional transfer on the economic outcomes of the receiving

[43] This policy instrument was first introduced in the 1995. Even-thought it has been regulated by different laws and acts, e.g., law 1607 of 2012 or the act 2924 of 2013.(Camacol (2016) p.25.) it has been always the same incentive caped at 4% of the value of each unit.

[44] The main reason to exclude these subsidies is that they are concentrated on a lower price threshold and the market forces are less relevant. The bunching at the price threshold at $135 \times mMW$ is the most pronounced. This paper aims to explain what happens around that cutoff.

households. The appendix figure 3.3.1 shows the evolution of those subsidies.[45] The program of 100 thousand free housing units occurred between 2012-2015. There is a program for rural housing and subsidies for the military that I ignore in this paper.

a. Total # of subsidies *b. Total amount of subsidies*

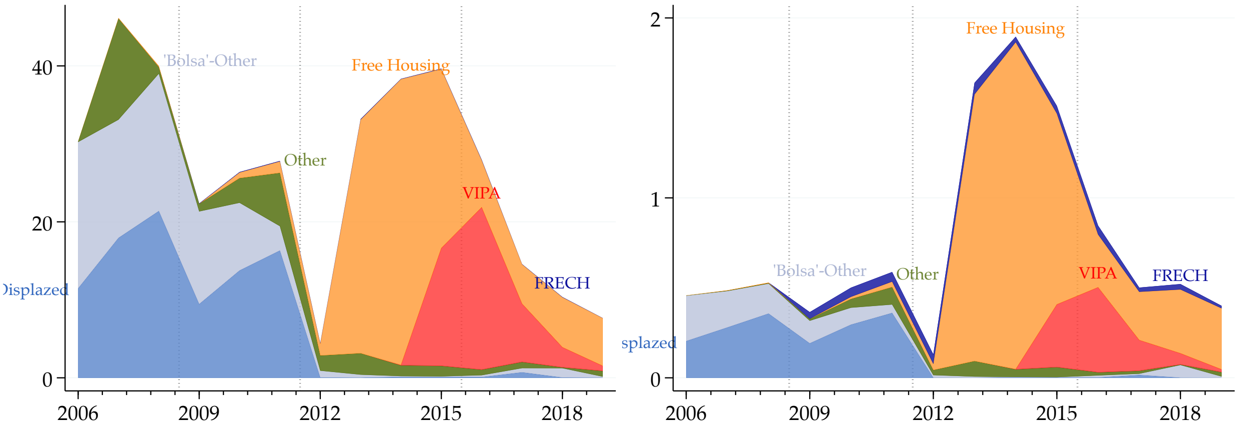


Figure A- 7: Subsidies for VIP

C. Interest rate subsidy details

Subsidies and Government Expenditure (VIP-$P(h) < 70$)

This figure shows the interest rate subsidies to all the different price levels

[45]There are other less relevant policies that intent to promote low-cost housing. Most of the additional policies did not change during my study period. Some of the policies are: i) No income tax for VIS credit. (Law 546 de 1999. This is between 5 and 8 percent of the value of the credits.) ii) Long term bonds to finance housing. (Law 546 de 1999.). iii) Tax exemption of leasing (2002) iv) Protection for credit defaults (Access to FNG (Fondo Nacional de Garandias)) v) New credit from the Colombian development bank to increase the credit for new housing. The housing with a limit of 70 MW is a free housing unit. these subsidies are apply to all housing units without targeting low-cost housing.

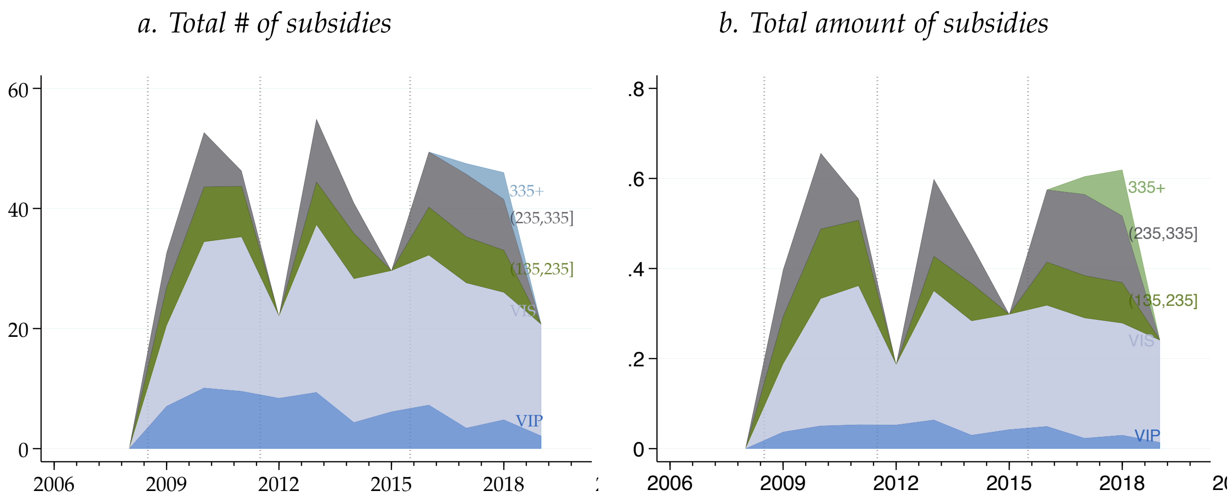


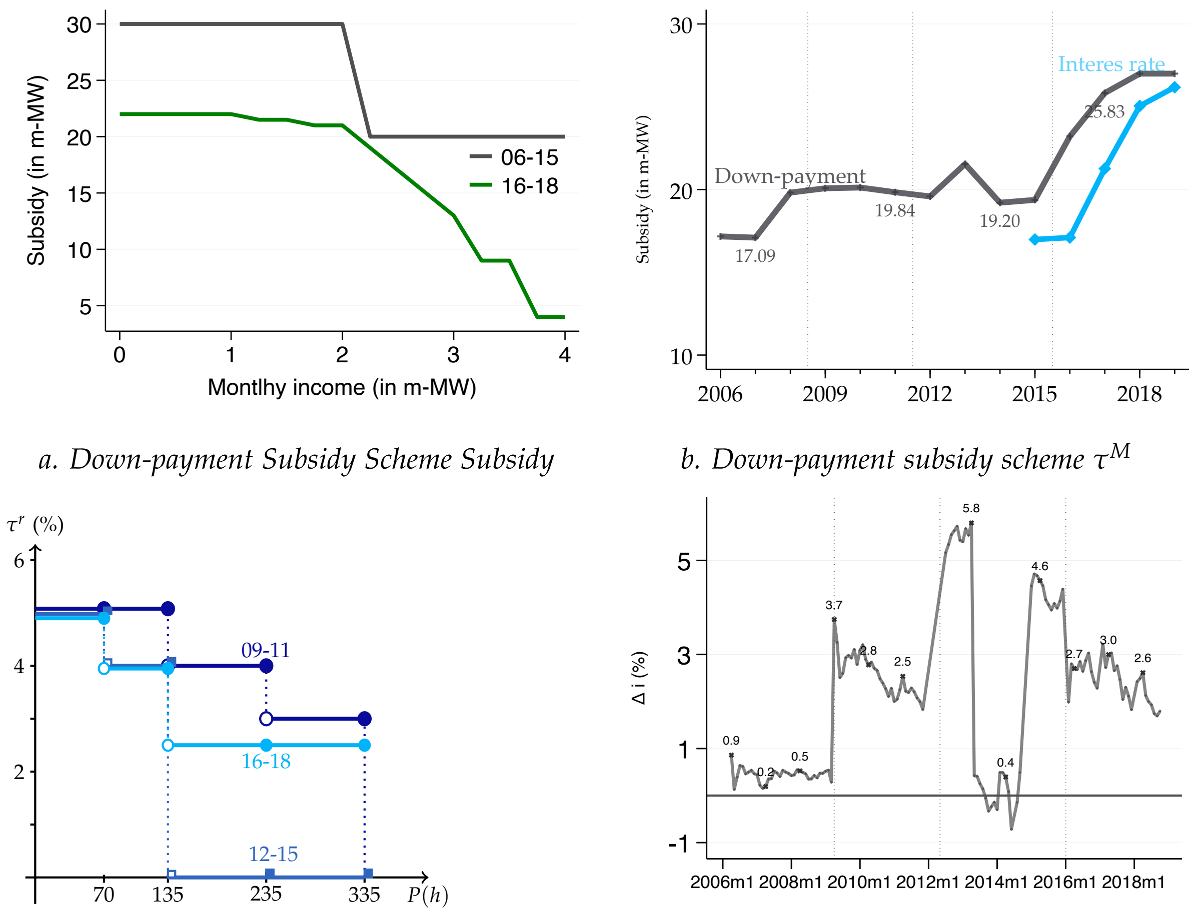
Figure A- 8: FRECH subsidies for different price ranges

Subsidy scheme. In contrast to the downpayment subsidy, interest rate subsidies were also available to households buying housing units above the 135×m-MW threshold. However, there is a notch at 135×m-MW. Figure 8 in the appendix shows the subsidies for the other house price ranges (i.e., higher than $135 \times mMW$). Figure 9c shows the subsidy scheme for the interest rate. Three different schemes existed during my study period. Each scheme is represented in the figure by a different line. The x-axis is the monthly minimum wage and the y axis is the discount in the interest rate. If a household gets the subsidy, the government pays the bank the corresponding amount during the first seven years of the loan.

Targeting instruments. The authorities use two different tools to determine eligibility; the households' income and the total price of the housing unit. A unit can be subsidized only if the market price is below the social housing threshold, 135 times the monthly minimum wage (m-MW). This arbitrary threshold is the same for all cities.[46] Regarding income, only households earning below four times the monthly minimum wage can get the subsidy. Figure 9a shows the subsidy scheme. Before 2015, the subsidy was decreasing on income, and the maximum possible subsidy

[46]This price limit is set by the government National Development Plan. The price limit was the same from 1997 until 2019. In 2019, with the law 1467 of 2019, the price limit increased to 150 m-MW for the 5 larger cities (including the metropolitan area) and remained the same in the other cities. Even tough the law came into effect in August, it was anticipated before (see for example a from a newspaper article is Tiempo (2019) from February 2019, or a report from the minister of housing from may (Ministerio de Vivienda, 2019) A low-cost housing unit (VIS) is a house whose total price is below a threshold of 135 monthly minimum wages (around 40 Thousand Dollars) and a lowest-cost unit (VIP) if, is below a threshold of 70 times the monthly minimum wages (around 20 Thousand Dollars)

was 22 × m-MW. In 2016 the generosity increased, the limit increase to 30 × m-MW for individuals with income below 2 × m-MW and 20 × m-MW for individuals with income between 2 − 4 × m-MW. As the figure 1 shows, the increase in the limit is reflected in higher government expenditure. Figure 9b the average subsidy during my study period. We can see that the average subsidies were about 20 percent before 2015 where the mean subsidy is about 26 percent.



a. Down-payment Subsidy Scheme Subsidy

b. Down-payment subsidy scheme τ^M

c. Interest rate subsidy scheme

d. Differences in Market interest rate i τ^r

Figure A- 9: Subsidy Scheme and observed mean differences

NOTE: Panel A. shows the the subsidy scheme. Panel B shows the observed subsidy difference between housing units above and below the 135 m-MW threshold. The left figure correspond to mortgage subsidy and the right figures to the interest rate subsidies. Source:

Other subsidies and policies. Other subsidies, excluded from the main analysis of this paper,[47] are the subsidies to disadvantaged populations. These subsidies exist to

[47]The main reason to exclude these subsidies is that they are concentrated on a lower price threshold and the market forces are less relevant. The bunching at the price threshold at 135 × mMW is the

follow a constitutional mandate of providing housing to people affected by forced displacement and environmental disasters. I exclude subsidies for rural housing and subsidies for the military.

The approach of relying on housing markets was ineffective to provide this type of housing. As a result, in 2014, a program to build 100 thousand free housing units was launched. The goal was to satisfy the constitutional mandate and provide housing to the disadvantaged population neglected by the previous policy approaches.A. G. Gilbert (2014) describes this program, *100 mil viviendas gratis*, and evaluates its potential effectiveness.(Camacho et al., 2020) evaluate this program. They study the effect of this conditional transfer on the economic outcomes of the receiving households. The appendix figure 3.3.1 shows the evolution of those subsidies.[48] The program of 100 free thousand housing units occurred between 2012-2015.

most pronounced. This paper aims to explain what happens around that cutoff.

[48]There are other less relevant policies that intent to promote low-cost housing. Most of the additional policies did not change during my study period. Some of the policies are: i) No income tax for VIS credit. (Law 546 de 1999. This is between 5 and 8 percent of the value of the credits.) ii) Long term bonds to finance housing. (Law 546 de 1999.). iii) Tax exemption of leasing (2002) iv) Protection for credit defaults (Access to FNG (Fondo Nacional de Garandias)) v) New credit from the Colombian development bank to increase the credit for new housing. The housing with a limit of 70 MW is a free housing unit. these subsidies are apply to all housing units without targeting low-cost housing.

Mortgage terms:

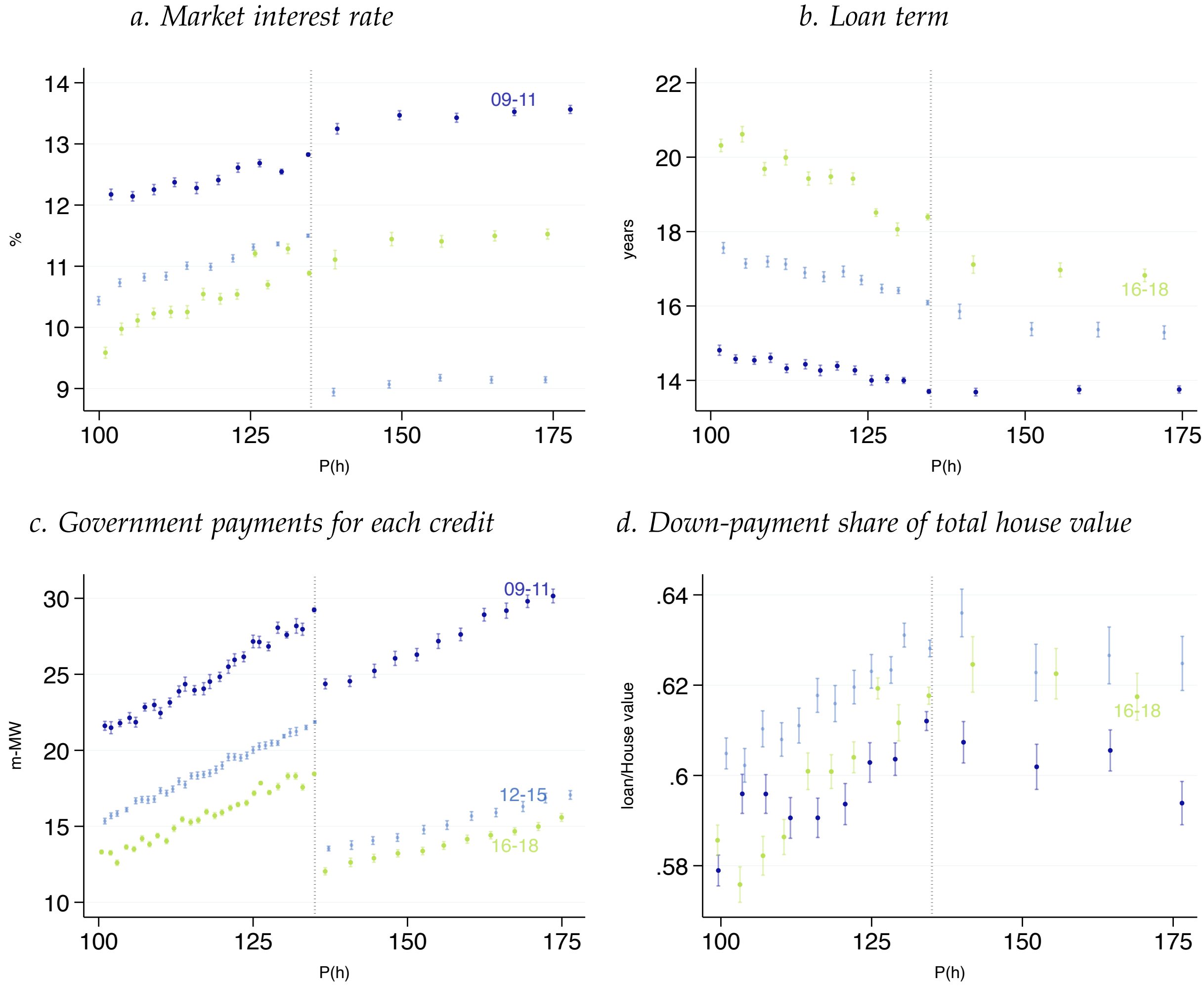


Figure A- 10: Loan terms

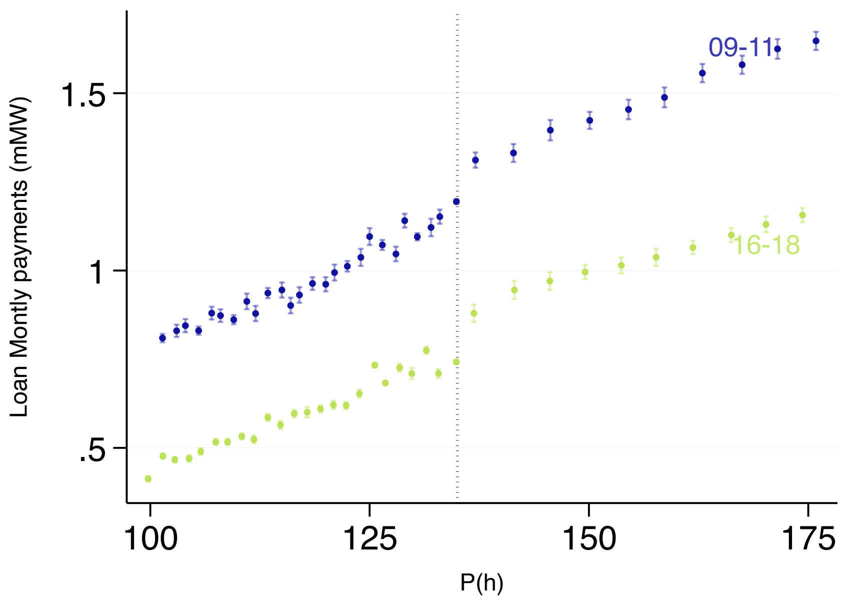


Figure A- 11: Comparing monthly payments around P(h)=135 m-MW

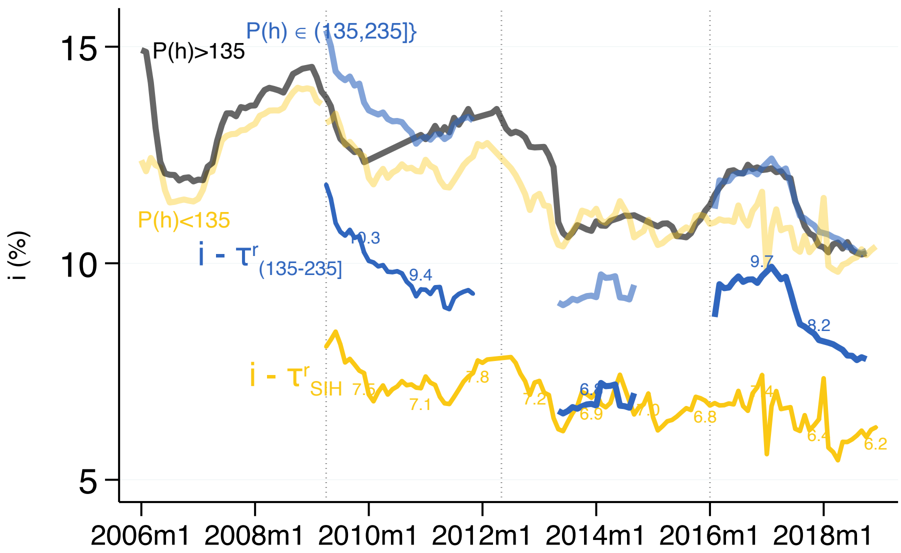


Figure A- 12: Market interest rate i and subsidy τ^r

NOTE: Panel A. shows the the subsidy scheme. Panel B shows the observed subsidy difference between housing units above and below the 135 m-MW threshold. The left figure correspond to mortgage subsidy and the right figures to the interest rate subsidies. Source:

Observed differences in monthly payments. I use the administrative records of these subsidies and administrative records on all loans to check that subsidies are reflected in the lower interest rates paid by households. The administrative records for the subsidies contain relevant information about the mortgages. It has the market interest rate i, the loan L, the term n, the discount in the interest rate τ^r, and the house price P. For more details about this data, see the data appendix in section **??**. The administrative records for all loans contain less detailed information, but I observe the interest rate of each loan and the average loan amount. I use the loans for housing, which have an indicator variable equal to 1 if the house is social housing and 0 otherwise.

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