Subsidies and Market Equilibrium. Evidence from a Notch in the Colombian Housing Market

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Abstract

In this paper, I study the effectiveness of a market-based approach to provide low-income housing. I study the expansion of a down payment subsidy and a mortgage interest rate discount to buy new housing in Colombia. I use a discontinuous policy cutoff, administrative and census data, and a housing market equilibrium model to estimate the relevant economic parameters of developers and households. I provide evidence of bunching at the price cutoff, suggesting that the housing market responds to subsidies' discontinuous incentives. The subsidy doubled during the study period and as a result, the bunching of houses sold at the maximum subsidy price increased from less than 1 percent to around 7 percent of the market share. Households buy housing units up to 30 percent smaller to benefit from the subsidy. Using the equilibrium model and estimated parameters, I find that the marginally subsidized households increased their utility by 9 percent by the end of the period. Developers receive a tax refund if they build housing below the price cutoff. Without this refund, their profits would be 14 percent lower.

I. Introduction

Governments around the world adopt different housing policies to satisfy the increasing demand for urban housing caused by rapid urbanization, and to avoid a housing affordability crisis. An important economic debate is whether governments should build low-cost housing or if instead they should subsidize developers or households and rely on the private sector. In the '90s, many countries stopped building public housing and implemented a marked-based approach providing subsidies for owner-occupied housing.[1] How does the housing market respond to these incentives? How do households and developers benefit from them? In this paper, I study an approach focusing on demand subsidies for homeowners of new housing units at the bottom of the income distribution. I use the Colombian setting which provides subsidized interest rates, a down-payment assistance subsidy and incentives to developers to build low-cost housing. I study the effects of these policies on the housing market and evaluate the subsidies' incidence.

Welfare evaluations of such policies need an accurate housing market equilibrium model and credible empirical estimates of housing market elasticities, which are scarce because of data limitations and lack of valid quasi-experimental variation.[2] Some papers exploit experimental variations in lotteries used to allocate over-subscribed social housing.[3] However, this works to evaluate the impact on an individual who receives the subsidy but not to understand the effect of subsidies on the housing market. Having reliable housing price data at a granular level is uncommon, particularly in the developing world. Modelling housing markets is also 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 welfare evaluation differs from the standard economic framework of perfectly competitive markets with homogeneous goods and agents.

This paper overcomes these challenges by studying the Colombia 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

[1]For example, the World Band 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).

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

housing unit.[4] Developers who build low-cost housing receive a tax incentive from the government, of up to 4 percent of the house price in refunds for VAT taxes paid on raw materials. A housing unit classifies as low-cost housing if its market price is below 135 times the monthly minimum wage (mMW) roughly 40,000 USD. The subsidy can only be used to buy low-cost housing. The arbitrary cutoff introduces nonlinear incentives for both developers and households to bunch at the price threshold.

These discontinuities and subsidies on the supply and demand side allow me to identify the relevant economic parameters of a housing market equilibrium model. In particular, I apply the model introduced by S. Rosen (1974) to my setting.[5] This economic model considers a competitive market[6] with heterogeneous buyers and sellers of a vertically differentiated good. I include the nonlinear incentives created by the Colombian subsidy scheme, and I show how the notch creates incentives for developers and households to bunch at the threshold.

To identify the model primitives, I propose an identification strategy based on the bunching literature and the two-step procedure implemented in the hedonic equilibrium literature. The first step follows the established practices to recover the implicit price function and the behavioural responses induced by the subsidy. In the second step, the discontinuity and estimated behavioural responses which allow observing two points on the same indifference curve to estimate its shape.

I can exploit the discontinuous incentive in the Colombian housing policy because of the existing unique data. I combine a census of all new construction with administrative records for the awarded subsidies from the Minister 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 pe-

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

[5]The literature started by S. Rosen (1974) is large and has been used extensively to model housing markets. 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) non parametric identification see.

[6]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.

riod, the interest rate subsidy was introduced, the downpayment subsidy increased, and eligibility expanded. As a result, the bunching moves from less than 1 percent 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 proposed the identification and estimation strategy in section 5. The results and welfare analysis are in section 6. I find an elasticity of substitution between housing and consumption of other goods of around 0.9. On the supply side, the cost function is increasing in unit size. 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.

On the supply side, I calculate the implied marginal costs and profits for the marginally subsidized developers. By producing at the price cutoff, developers produce at a higher marginal cost. 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.

Related Work and Contribution

I make methodological and empirical contributions to three different literatures. My main contribution to the bunching literature is to provide a framework to recover structural parameters using bunching responses in an vertically differentiated product market equilibrium. The particular Colombian setup that offers subsidies to the supply and demand using the same price threshold, allows me to recover parameters describing the utility function of households and developers' cost function. The original approach used the bunching moments to derive reduced form elasticities and used them as sufficient statistics for welfare analysis. However, more recently, some papers use the bunching evidence and moments to estimate the structural parameters of economic models. For example, Einav, Finkelstein, and Schrimpf (2015) use it study spending response along the entire nonlinear budget set in the drugs market, Best, Cloyne, Ilzetzki, and Kleven (2019) propose a model and an estimation approach to recover the intertemporal elasticity of substitution (IES) from bunching responses in the mortgage market. Chen, Liu, Suárez Serrato, and Xu (2021) use it to estimate the differences between reported responses and real R&D to discontinuous incentives designed to increase R&D in China. My paper follows and complements these approaches.

The framework, or the insights used in this paper, could be used in other housing markets with nonlinear incentives or in other markets with vertical differentiation such as computers or labor market. For example, 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 Angels, USA. However, these papers report the bunching as a result without a framework to interpret this bunching or to use it to recover economic parameters of interest. Carozzi et al. (2020) present an economic model but they do not use it to interpret the bunching estimates. Instead, they use it to do some comparative statics and get some prediction about the possible effects of the subsidy. There is also evidence of bunching on the density of mortgages around the interest rate threshold introducing notches in the mortgage interest rates 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. My paper complements this evidence of bunching in housing markets, a relatively unexplored setting.[7]

[7] 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, Friedman, Olsen, & Pistaferri, 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),

I also contribute to the literature on estimating sorting or hedonic models. There are different identification approaches to recover the primitives of such models. See Greenstone (2017) and Kuminoff et al. (2013) for surveys of the literature. Epple et al. (2020) and Chernozhukov et al. (2021) are recent approaches. However, the lack of credible experimental variation used in these approaches is less credible. I propose a new identification approach using the arbitrary discontinuity.

The final contribution is to the housing policy literature. Most papers studying housing policies evaluate the impacts on individuals, which is a relevant but different question. This paper complements the existing literature by providing evidence on an understudied type of policy for a developing country. 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?[8] If we provide subsidies, should we subsidize developers, households or both?[9] What is the incidence of such subsidies or taxes?[10]

II. Subsidies Over-time and Notch

This section introduces the subsidies and discontinuity I use to study the effect of housing subsidies on the housing market, it describes the subsidy expansion of the last decade, 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.[11] Since the '90s, Colombia and other Latin American countries

overpay hours (Goff, 2021; Bachas & Soto, 2018; Abel, Dey, & Gabe, 2012), marriage market (Persson, 2020), Crime, (Goncalves & Mello, 2021) among others.

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

[9] 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)

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

[11] 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

changed their approach, moving from state-provided housing to a market-based solution. 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 households and their developers. On the demand side, the main policy tools are mortgage assistance through a downpayment subsidy and a subsidized interest rate. On the supply side, the policy tool is a tax refund for developers who build low-cost housing. This approach is similar to *help to buy* in the UK or some first time buyers programs in the USA.

The discontinuity. The policy design relies heavily on the definition of low-cost housing. Most of the subsidies apply only for 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).[12] This arbitrary threshold is the same for all cities, and the change overtime is only due to changes in the minimum wage.[13] There is an additional definition creating a similar discontinuity at a lower price cutoff. Housing units below $70 \times mMW$ are defined 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 in 2009, and in 2016 the downpayment subsidy increased and a new housing policy program *Mi Casa Ya* was introduced. With this program, all households earning below $4 \times mMW$

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.

[12]In Colombia the minimum wage is adjusted every year based on the inflation. Figure **??** in the appendix

[13]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)

became eligible and automatically receive the down payment and interest rate discount. Based on these changes, I divide my study period into subperiods to study how the housing market responds to changes in the generosity of subsidies promoting the demand of low-cost housing.

The four periods are

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

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

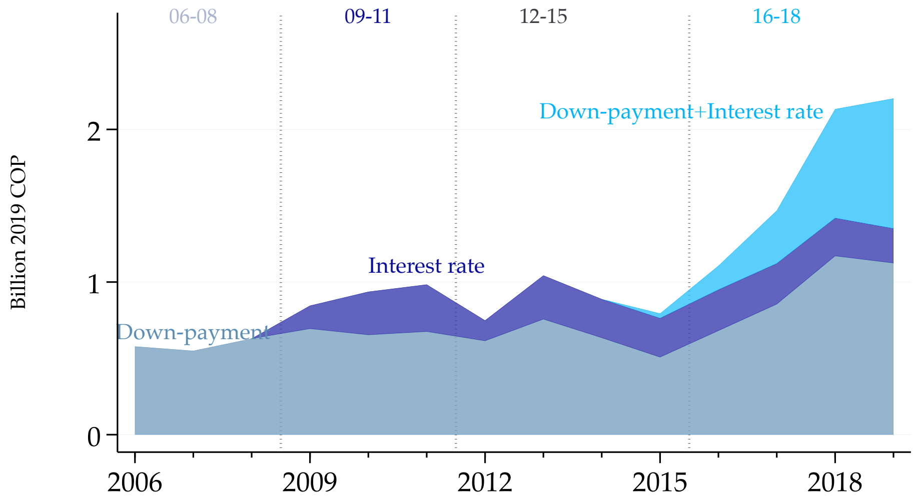
12-15 Unstable period with rapid changes in the interest rate subsidy and the existence of programs targeted at the extreme poor.[14]

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 number of subsidies and total government expenditure from 2006 until 2018. 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 low-cost housing unit. The **dark blue** area in Figure 1 shows the number of subsidies and total government expenditure from 2011 until 2018. 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.

[14] *100 thousand free housing*, and VIPA subsidy for vulnerable population.More details in the appendix.

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. The total amount is assigned to the year of the subsidy assignment. This amount is calculated 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 Minvivienda and FRECH. More details about the data in appendix 2

Supply Subsidy–VAT tax refund. In 1995, a couple of years after the down-payment subsidies were introduced, 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.[15] I include this subsidy in the analysis. Accounting for this subsidy introduces nonlinear incentives on the supply side.

C. The Notch

The combination of the arbitrary definition of low-cost housing and the different policy tools explained in the previous section create discontinuous incentives, or notches, around the cutoff defining low-cost housing. The notch increases over time as a response to the introduction of new programs and the increase in the size of the subsidy. In this subsection, I explain in more detail the notch and its increase over time.

[15]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.

Relevant Prices. There are three different prices given the subsidy scheme. Transaction or market price, $\mathbf{P}$. Developers Price-$\mathbf{P}^{\delta}$ or the per unit price developers receive 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 in this paper and is the basis to study the effect of subsidies on the housing market. Formally,

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

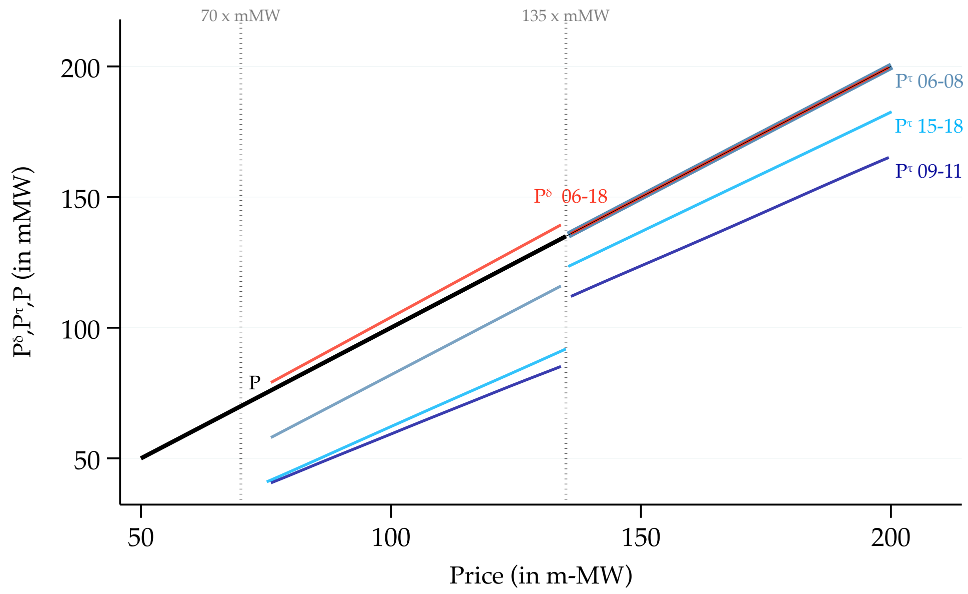
where, $\delta = 4\%$ is the tax refund rate, $\tau = \tau^{m} + \tau^{i}$ is the total amount of money a household receives from the government. τ^{m} reresents the money received for the down-downpayment and τ^{i} is the money received from the interest rate discount.

Figure 2 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 and is 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 different 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. This is represented in the graph by the red line being above the black line. A household buying a housing unit below the cutoff qualifies for the subsidy and therefore 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 also below the black line. However in all the cases there is a notch for the household's price at the cutoff. The slope in the blue lines including the interest rate subsidy is explained by the fact that the subsidy is higher as the mortgage increases. The amount paid by the government is calculated using a typical mortgage at each price level.[16] 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.

[16] For more details on the data sources and the mortgages see appendix **??** and **??**

Figure 2: The Notch



Note: Source: Administrative Records from 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 interest rate subsidy was introduced, households buying a unit priced above the cutoff, pay the full price. In the graph this is represented by the black and blue line coinciding above the cutoff. The dark blue line shows the price paid by a household that gets the downpayment 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 above the cutoff. Additionally, they can get the downpayment subsidy. These two subsidies combined increase the notch. The light blue line shows the price paid by households who get the two subsidies after the introduction of the program *mi casa ya* and the increase in the downpayment subsidy. During this period, there was a drop in the interest rate and therefore the interest rate subsidy is 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 downpayment 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. In addition to the 100 thousand free housing units priced at $70 \times mMW$ or below the interest rate, the subsidy was modified many times. Although, for completeness, I include this period when presenting the data and results, I see it as a transition period and therefore do not pay much attention to it.

The notch size. Table 1 shows the size of the jump at the cutoff during my study period. It also shows the jump separately by subsidy type.

Table 1: Notch and number of subsidies by period

	Notch *(in mMW)*			Subsidies *(in thoushand)*		
	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

III. Housing Market Responses

This subsection introduces the housing market data and the main descriptive facts. First I introduce the data, then I present evidence of bunching in housing price. I then introduce the hedonic price for housing characteristics and the standard housing unit transformation. Then 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 *Coordenadas Urbanas* census collected by the Colombian Chamber of Construction-CAMACOL and containing all new construction units built in 126 Colombian municipalities from 2006 to 2018.[17] The unit of observation is a type of housing. If there are three different types of units in a housing project, for example, a studio, one-bedroom, and two bedrooms, I observe the price and characteristics of each of these unit types separately. The data is collected monthly, and it tracks the evolution of each project over time. The data includes all housing projects of 300 m^2, and excludes small single-family homes and informal housing. Additionally, 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.

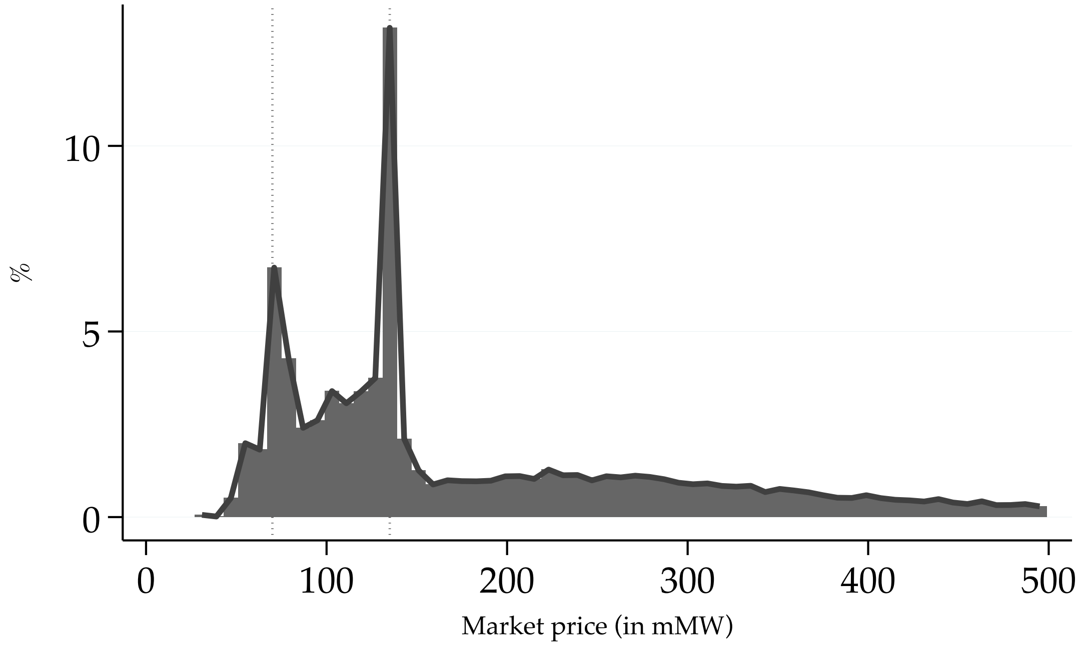
[17]Not all cities have information starting in 2006. Some cities where included in later

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 listed market *Prices* 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, the monthly minimum wage is set nationally and adjusted every year based on inflation. See figures **??** in the appendix. In most of the 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 shows how the subsidy scheme creates incentives for households and developers to buy and build housing units priced 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 housing units that can be subsidized.

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



NOTE: NEED TO WORK ON THESE AND ALL THE NOTES

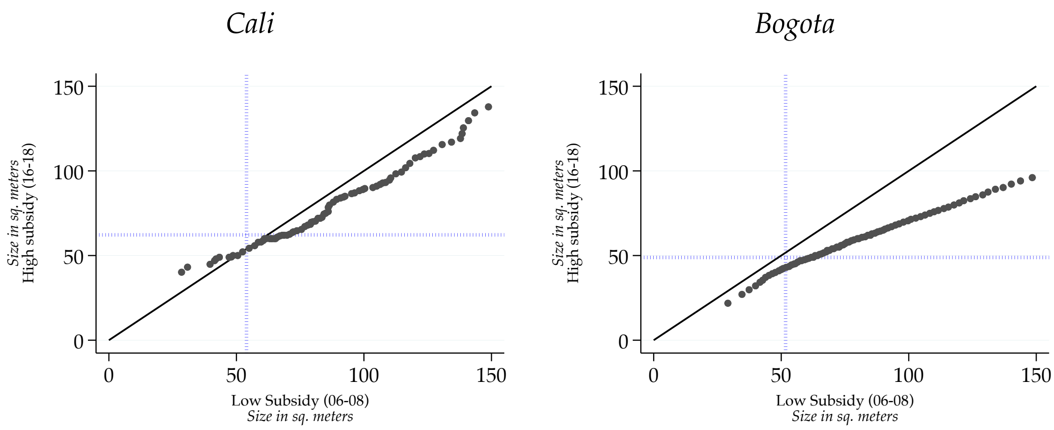
Market adjustment. How does the market adjust to reach this equilibrium? The mechanism explored in detail in this paper, is that households and developers adjust the characteristics of the housing units they buy and produce to take advantage of the subsidies. Figure 4 provides suggestive evidence that housing stock characteristics are affected by the subsidy scheme. Additionally, the construction sector is perceived as highly competitive and developers have no incentive to build bigger units when, for the same price, households are willing to buy smaller ones.[18]

Size Response. Figure 4 shows the quantile of 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). 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 in the 45 degree line. The blue dotted lines

[18]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 implies any cost for developers.An alternative explanation is that households and developers buy and produce the same type of units they would buy in the absence of the subsidy but developers reduce the price if the housing unit is priced above the cutoff allowing households to get the subsidy.Although it is a possibility the arguments presentent in this paragraph suggest this is an unlikely scenario.

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



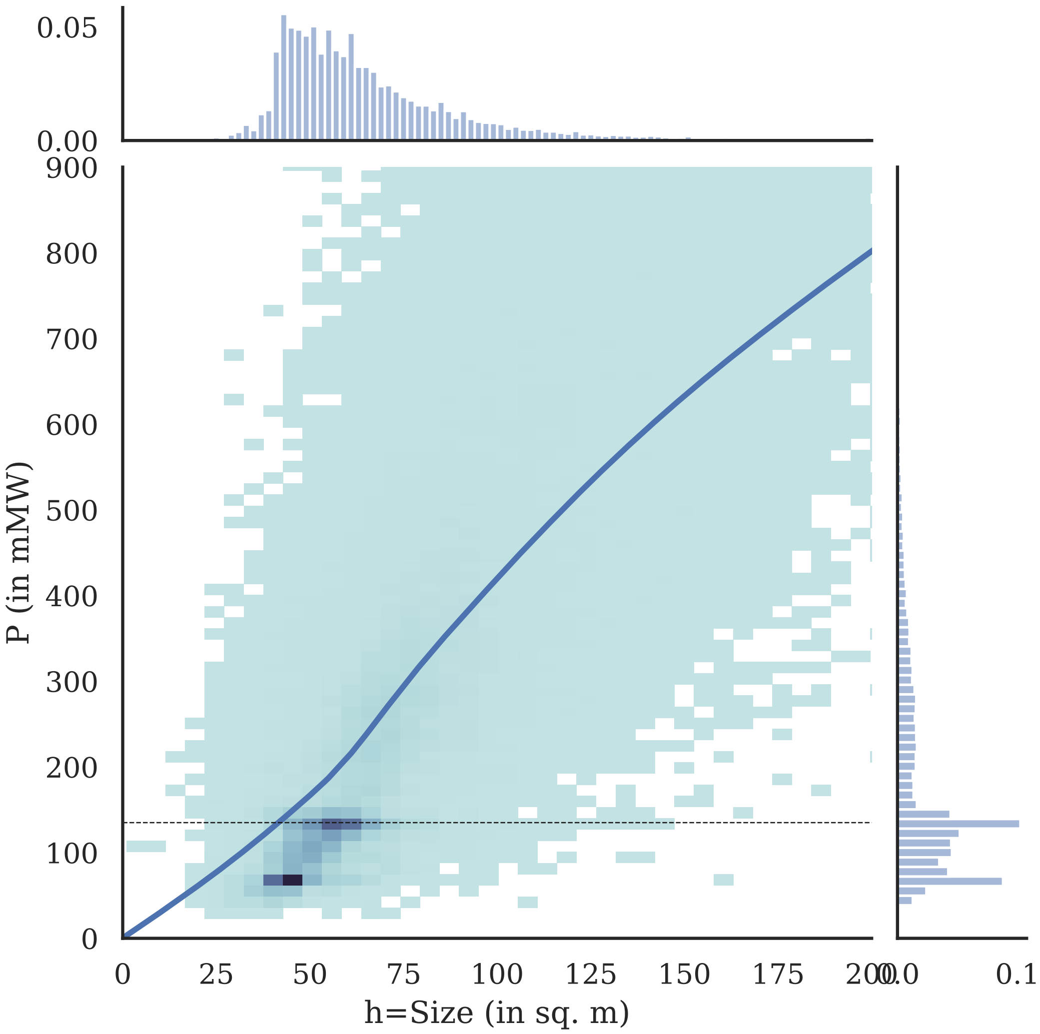
Note:

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). Colour intensity represents the joint density. In each submarket, heterogeneous agents are buying and selling units with different characteristics. The same money may buy bigger housing units in separate submarkets. Consequently, there is excess mass at different housing sizes.

Main housing characteristic. Housing units differ in many dimensions and cannot be easily summarized into a single variable. However, focusing on a single characteristic makes the empirical analysis and modelling more tractable. In this paper, I focus exclusively on housing size for several reasons. First, although size is not a commonly observable variable, its measurement is incontestable.[19] Second, people prefer larger houses. Third, the housing size is a continuous variable which simplifies the modelling approach. Because my data includes it, this natural choice is feasible.

[19]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.

Figure 5: Observed Market Equilibrium



NOTE:

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 relationship between size and price. As expected, there is a positive relationship between price and size. The line also shows that the equilibrium price function may not be linear. However, this unconditional relationship may not represent the equilibrium marginal willingness to pay and supply housing size. I follow common practice in the hedonic literature to estimate the equilibrium implicit price of size.[20] Equation 1 represents a general specification for the price function. Housing size is represented by s_{ltc} and all other housing characteristics are defined by a vector X_{ltc}, and ω_{ltc}, represents the residual containing all 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:[21]

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

Independence conditional on observables. It is common to rely on conditional independence to recover the implicit price function of a certain characteristics.[22] 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[23].

Discussion about the assumptions. This assumption can be problematic in many settings. For example, Chay and Greenstone (2005) show that using an hedonic model

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

[21]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.

[22]

[23]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)

to recover the marginal willingness to pay for air quality without using instruments generates biased results. Eventough omitted variables can also generate a bias in my setting, there are 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 the house can be extended to have an extra bathroom or bedroom in the future, 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 it does not affect the size coefficients is ensuring. However, this does not rule out the fact that other omitted variables could bias the result. For example, if the bunching is generated by changes in price without any 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 differing only in size. 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 data. Solving for h in the equation 4, I get the standardized size measure,

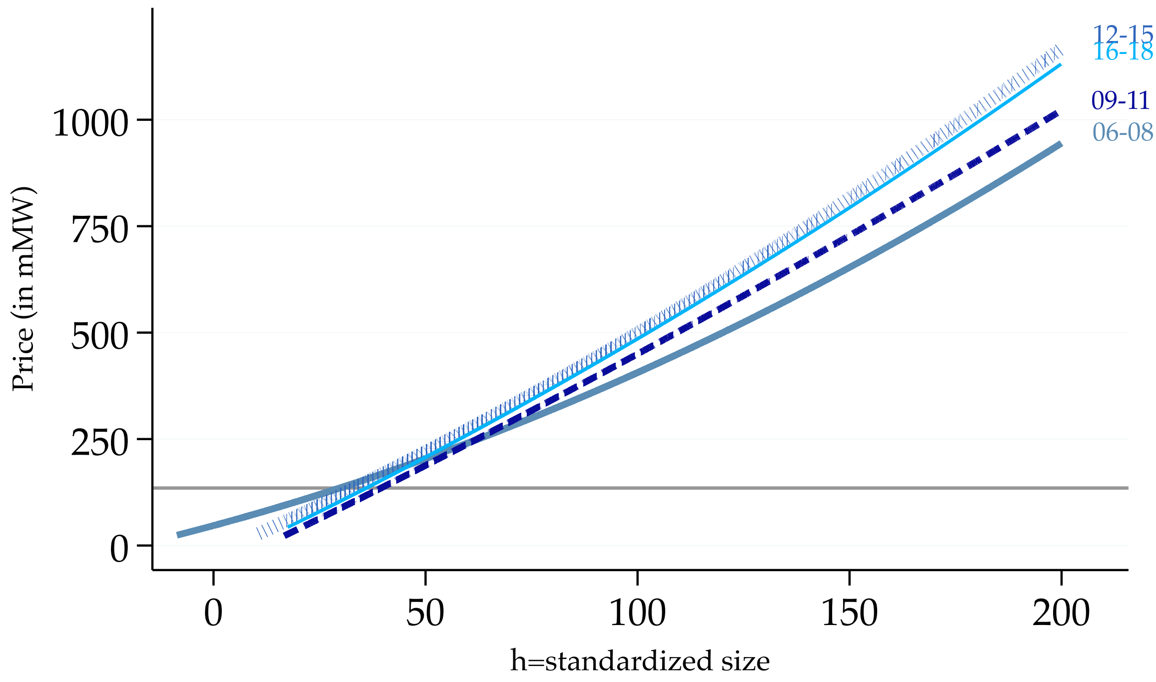
$$h_{ltc} = \rho^{-1}\big(\rho\left(s_{ltc}\right) + \Gamma'\left(X_{ltc} - \bar{X}_{ltc}\right) + \left(\omega_{ltc} - \bar{\omega}_{ltc}\right)\big) \tag{5}$$

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 estimate this price by periods, and I standardize the units in a way that $\rho\left(\bar{s}_{ltc}\right) + \Gamma' \bar{X}_{ltc} + \bar{\omega}_{ltc}$ is the observed average price for the average house in each period. For the implicit price function, I use a parametric approximation

$\rho(s) = \rho_0 + \rho_1 \cdot s + \rho_2 \cdot s^2$.[24]

Figure 6: Implicit price for housing size



Note: This figure shows the implicit price for normalized sized h for 4 different periods. The controls included in the vector X 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. I include more detail characteristics such as a dummy variable equal to one if the unit has a porch, a studio, storage unit, dressing room, service room, dining and living room, fire place, kitchen, clothes areas, patio, and potential to extend to an extra bathroom or bedroom and location coordinates. The specifications including this refined set of controls are similar. It also includes lot size, number of building blocks, apartments per floor, number of floors, total parking spots, and number of building units.

Figure 6 shows the functional form of the estimated price function for 4 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 over time. This could be explained by the changes in the market induced by the subsidy and by changes in the natural evolution of the market. One of the objectives of the economic model introduced in the next section is to explain how

[24]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.

this equilibrium price gradient is determined. Additionally, independently of the nature of its determination, the estimation of the behavioural parameters needs to account for these changes in the equilibrium implicit price.

Implied maximum size of a standard subsidized unit

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

D. Bunching as a Behavioural Response

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 size. This subsection shows the evolution of the bunching over the period when the government expenditure on these subsidies doubled.I follow the techniques introduced in the bunching literature (Kleven, 2016) to create a counterfactual distribution.[25]

Counterfactual Distribution Estimation

I follow the bunching literature to estimate the excess mass and the behavioural responses, which in this case are changes in the housing size. Developers and households build and purchase smaller houses to take advantage of the subsidy.

Define $T(h)$ as the change in observed density f_{h^*} relative to the counterfactual distribution f_{h_0},

$$T(h) = f_{h^*} - f_{h_0} \tag{6}$$

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

$$\Delta h = \overline{h} - \underline{h} \tag{7}$$

Intuition. The counterfactual is the distribution that would exist in the absence of the subsidy. I calculate it fitting a flexible polynomial to the observed density and

[25]In this case, I am assuming that 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.

excluding the observations around 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 $2 \cdot \epsilon$,

$$h_b = \frac{1}{N} \sum_{l=1}^{N} \mathbb{1} \left[h_l \in (b - \epsilon, b + \epsilon) \right] \tag{8}$$

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, $exc_L^H (h_b)$,

$$h_b = l(h_b) + exc_L^H (h_b) + v_b \tag{9}$$

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

$$\hat{f}_{h_0} = \hat{l}(h_b) = \sum_{p=0}^{T} \hat{\iota}_p h_b^p \tag{10}$$

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

$$\hat{T} (\underline{h}) = \hat{f}_{h^*} (\underline{h}) - \hat{f}_{h_0} (\underline{h}) \tag{11}$$

Equation **??** 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.

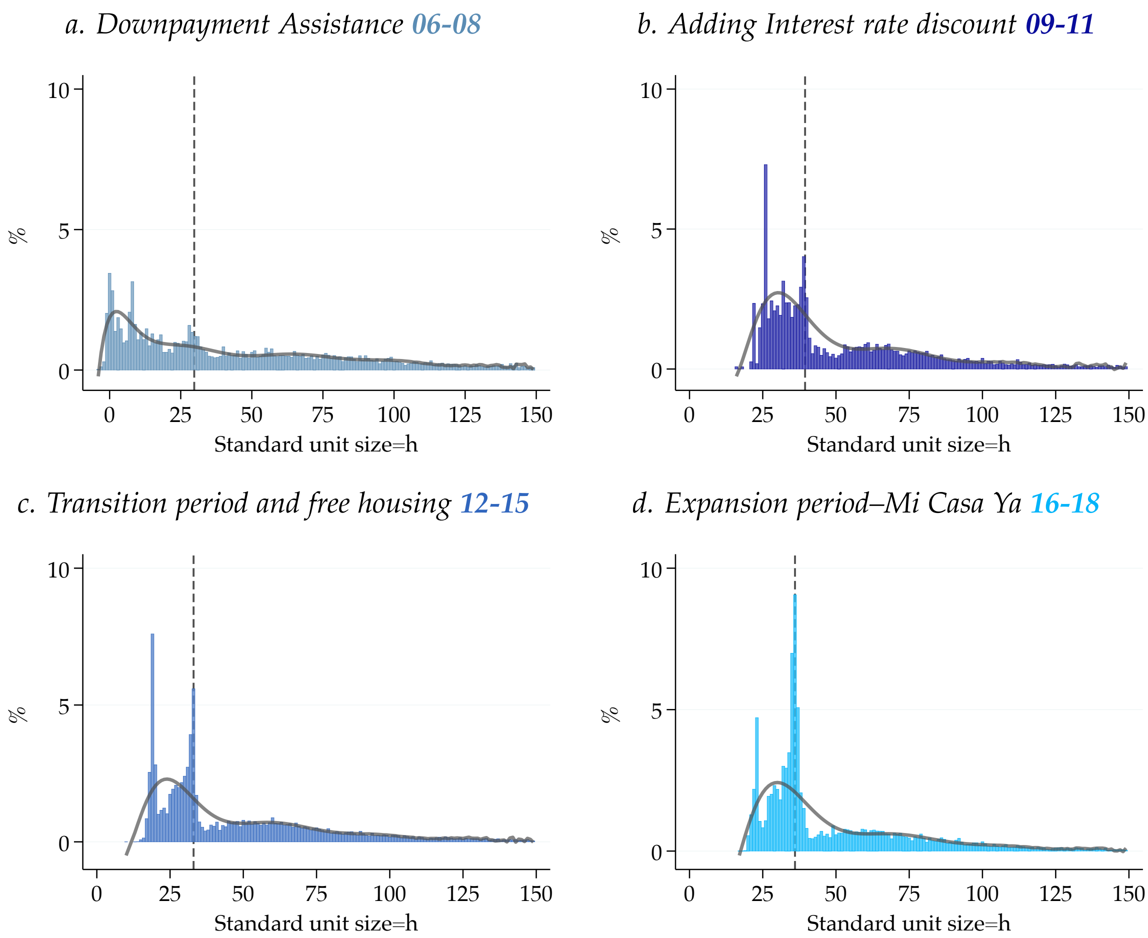
Maximum behavioural response. The maximum behavioural response, $\overline{h}$ is obtained when the counterfactual and observed distribution coincide.

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

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 $\hat{T}(\underline{h})$ at the cutoff $\underline{h}$ is the share of households that reduce their housing consumption to get the subsidy. Because this behaviour is the result of 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.

Figure 7: Equilibrium Density by $\tilde{h}$



Note:

The bunching responses are more pronounced as the government expenditure on subsidies increases. Figure 7 shows the distribution of the standardized units for the periods when subsidies change, and a solid grey line for the counterfactual distribution. Table **??** shows the estimates of the relevant behavioural responses. The subsidy creates a small bunching when only downpayment 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 12.7pp of the market share, compared to 5.52pp in the transition period, 3pp in the interest rate period and 1.2pp at the baseline.

Table 2: Behavioral Responses Estimates'

	06-08	09-11	12-15	16-18
Behavioural Responses				
$\int_{h_{min}}^{\underline{h}^-} T(h)\mathrm{d}h$	1.03	0.86	3.80	7.28
$\hat{T}(\underline{h})$	0.50	2.02	4.01	6.97
$\int_{h_{min}}^{\underline{h}} T(h)\mathrm{d}h$	1.54	2.88	7.81	14.2
$\int_{\underline{h}}^{\bar{h}} T(h)\mathrm{d}h$	-0.12	-6.23	-4.27	-3.38
$g(\underline{h})$	0.73	1.28	1.07	1.43
h_{min}	26	37	29	32
$\underline{h}$	29.8	39.4	33.0	36.0
$\bar{h}$	40	53	45	49

Unit supply Function

How do developers respond? One of the main objectives of the economic model is to address question in more detail. However, before introducing the model, I explore the relationship between the unit size and the number of units. Figure 8 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 trade off the number and size of housing units.

Figure 8: Unit supply function

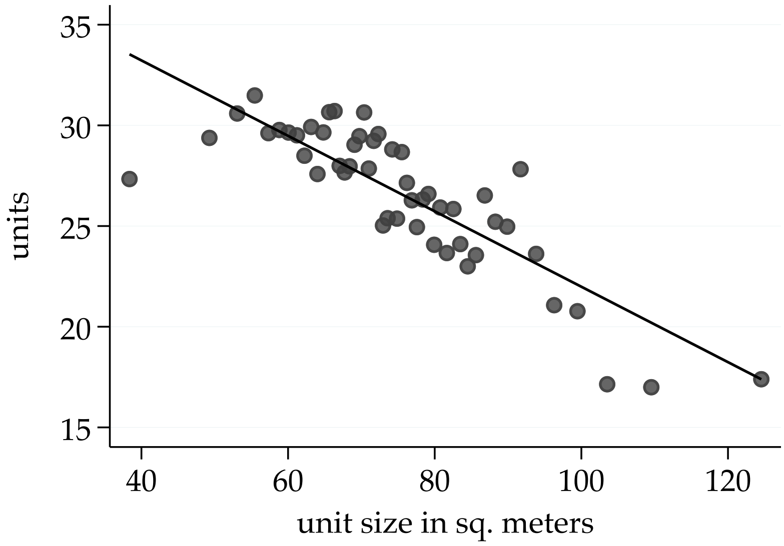


Table 3 shows estimates of the model in equation 12 by period and with and without the set of controls X_{ltc}.

$$Q_{ltc} = \alpha_0 + \alpha_1 s_{ltc} + \alpha_x' X_{ltc} + +\epsilon_{ltc}^{Q} \tag{12}$$

The coefficients in table 3 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 over time.

Table 3: 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
Observations	11906	11889	15056	15029	20950	20881	15756	15418

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

To help answer the opened questions from the previous section, 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, illustrate how the equilibrium hedonic price function is achieved. Third, motivate a novel identification approach to recover the household's and developers' behavioural parameters. Getting the estimates for the behavioural parameters allows an incidence's evaluation of the subsidies.

A. Model Set Up

The proposed model introduces the discontinuous incentives produced by the subsidy scheme to a standard hedonic or sorting model.[26]

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. N households looking to buy a *new* housing unit are indexed by i. They are heterogeneous on income $Y_i \sim F_Y$.[27]. 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.

[26] 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).

[27] 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

Developers J 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 $B(h_j, Q\left(h_j\right); \beta)$[28] 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 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 This model is in essence a matching model. 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 households demanded and produced densities to match.

B. Optimal choices

Prices

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

$$\text{Market:} \quad P\left(h; \boldsymbol{\rho}\right) \tag{13}$$

$$\text{Household:}\ P^{\tau}\left(h, \tau; \boldsymbol{\rho}\right) = P\left(h; \boldsymbol{\rho}\right) - \tau \cdot \mathbb{1}\left[P\left(h; \boldsymbol{\rho}\right) \leq \lambda\right] \tag{14}$$

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

[28]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

Differences in prices. A household getting a subsidy pays $P^{\tau}(h,\tau;\boldsymbol{\rho})$ instead of $P(h;\boldsymbol{\rho})$ 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, $P(h,\rho) < \lambda = 135\,mMW$. 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 prices, and δ would represent a premium to build low-cost housing.

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

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.

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

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*,[29] and the bid and offer functions to characterize the optimal choices.

[29] 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 $p_c = 1$

Bid functions (or indifference curves) The bid functions,$\varphi_D(h, Y, \bar{U}; \theta)$ 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,

$$\bar{U} = U(h, Y_i - \varphi_D; \theta) \tag{16}$$

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

$$\varphi_j^s = \frac{B\left(Q^s(h;\alpha), A_j; \boldsymbol{\beta}\right) + \bar{\pi}}{Q^s(h;\alpha)} \tag{17}$$

Tangency conditions

Households Households choose their housing size h to maximize their utility. Because of the notch in the budget set, the standard *optimally conditions* do not correspond to the optimal choice for all households. Let's define the *optimality conditions*,[30]

$$\frac{\partial P(h, \boldsymbol{\rho})}{\partial h} = \frac{\dfrac{\partial U(h, C; \theta)}{\partial h}}{\dfrac{\partial U(h, C; \theta)}{\partial C}} \tag{18}$$

Assuming that equation 18 has a unique solution and using the budget constraint, $P^\tau(h, \tau; \boldsymbol{\rho}) - Y_i = C_i$., we can *solve* for h^*, the housing choice satisfying the *tangency conditions*.[31]

$$h^*(Y_i, \tau; \theta, \boldsymbol{\rho}, \lambda) = \begin{cases} h(Y_i + \tau; \theta, \boldsymbol{\rho}) & \text{if } P(h; \boldsymbol{\rho}) \leq \lambda \\ h(Y_i; \theta, \boldsymbol{\rho}) & \text{if } \lambda < P(h; \boldsymbol{\rho}) \end{cases} \tag{19}$$

[30]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 $p_c = 1$

[31]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.

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

$$\frac{\partial \varphi^s\left(h, A_j; \boldsymbol{\beta}, \bar{\pi}\right)}{\partial h} = \begin{cases} \dfrac{\partial P\left(h, \boldsymbol{\rho}\right)}{\partial h} \cdot (1+\delta) & \text{if } P\left(h; \boldsymbol{\rho}\right) \leq \lambda \\ \\ \dfrac{\partial P\left(h, \boldsymbol{\rho}\right)}{\partial h} & \text{if } \lambda < P\left(h; \boldsymbol{\rho}\right) \end{cases} \tag{20}$$

We can solve 20 for h, and get and expression for the tangency conditions,

$$h^*\left(A_j, \delta; \boldsymbol{\beta}, \boldsymbol{\rho}, \lambda\right) = \begin{cases} h\left(A_j, \delta; \boldsymbol{\beta}, \boldsymbol{\rho}\right) & \text{if } P\left(h; \boldsymbol{\rho}\right) \leq \lambda \\ h\left(A_j; \boldsymbol{\beta}, \boldsymbol{\rho}\right) & \text{if } \lambda < P\left(h; \boldsymbol{\rho}\right) \end{cases} \tag{21}$$

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* $Y_i = \underline{Y}, A_j = \underline{A}$

$$h^*\left(Y_i, \tau; \theta, \boldsymbol{\rho}, \lambda\right) = \underline{h} \text{ and } h^*\left(A_j, \delta; \boldsymbol{\beta}, \boldsymbol{\rho}, \lambda\right) = \underline{h} \tag{22}$$

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

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

$$U\left(Y_i - P^\tau\left(h^*\left(Y_i, \tau; \theta, \boldsymbol{\rho}, \lambda\right), \tau; \rho\right), h^*\left(Y_i, \tau; \theta, \boldsymbol{\rho}, \lambda\right); \theta\right) < U\left(Y_i - P^\tau\left(\underline{h}, \tau; \boldsymbol{\rho}\right), \underline{h} : \theta\right) \tag{23}$$

$$\pi\left(Q(h^*\left(A_j, \delta; \boldsymbol{\beta}, \boldsymbol{\rho}, \lambda\right)), \overline{A}; \boldsymbol{\rho}, \delta\right) < \pi\left(Q(\underline{h}), \overline{A}; \boldsymbol{\rho}, \delta\right) \tag{24}$$

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

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

$$\begin{aligned} h^*\left(\overline{Y}, \tau; \theta, \boldsymbol{\rho}, \lambda\right) = \overline{h} \iff \\ U\left(\overline{Y} - P^{\tau}\left(\overline{h}, \tau; \boldsymbol{\rho}\right), \overline{h}; \theta\right) = U\left(\overline{Y} - P^{\tau}\left(\underline{h}, \tau; \boldsymbol{\rho}\right), \underline{h} : \theta\right) \end{aligned} \tag{25}$$

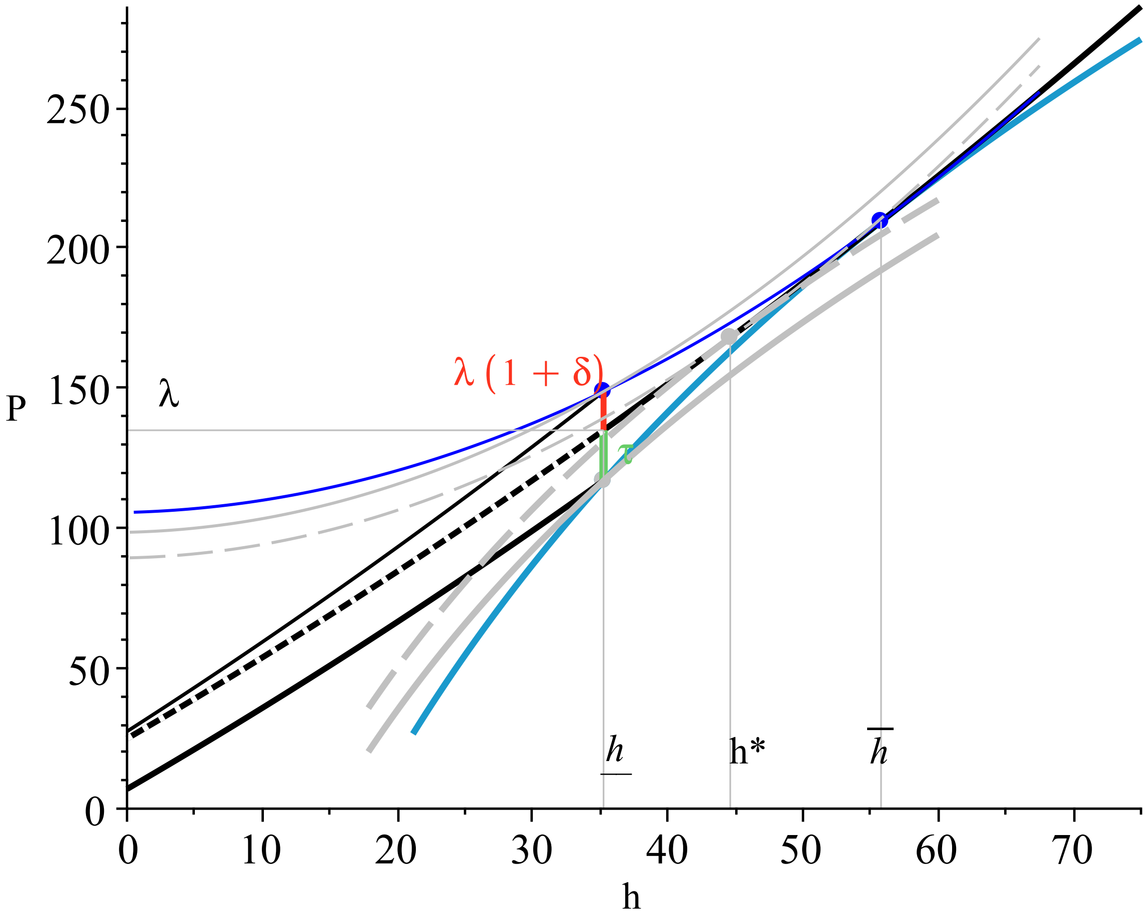
$$\begin{aligned} h^*\left(A_j, \delta; \boldsymbol{\beta}, \boldsymbol{\rho}\right) = \overline{h} \iff \\ \pi\left(Q(\underline{h}; \alpha), \overline{A}; \boldsymbol{\rho}, \delta\right) = \pi\left(Q(\overline{h}; \alpha), \overline{A}; \boldsymbol{\rho}, \delta\right) \end{aligned} \tag{26}$$

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

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

Figure explanation. Figure 2 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 2a, 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 2. 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 1.1 the figure 2 shows the examples of the optimal choices for other developer types.

Figure 9: Marginally Subsidized and Marginal Buncher agents choices



Note:

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

$$h^{\mathrm{D}}\left(Y_i;\tau,\theta,\boldsymbol{\rho},\lambda\right)=\begin{cases}h^*\left(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda\right) & \text{if } Y_i\leq \underline{Y}\\ \\ \underline{h} & \text{if } \underline{Y}<Y_i<\overline{Y}\\ \\ h^*\left(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda\right) & \text{if } \overline{Y}\leq Y_i\end{cases} \tag{27}$$

$$h^{\mathrm{S}}\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho},\lambda\right)=\begin{cases}h^*\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho},\lambda\right) & \text{if } A_j\leq \underline{A}\\ \\ \underline{h} & \text{if } \underline{A}<A_j<\overline{A}\\ \\ h^*\left(A_j,\delta;\boldsymbol{\beta},\boldsymbol{\rho},\lambda\right) & \text{if } \overline{A}\leq A_j\end{cases} \tag{28}$$

C. Market Level Supply and Demand

Productivity and Income mapping to housing size.

Because households only differ by income level Y_i, and under the assumption that $h^*\left(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda\right)$ is strictly monotone, it is possible to know the household income from the choice of housing satisfying the optimality conditions.[32]

$$Y_i=\tilde{Y}\left(h,\tau;\theta,\boldsymbol{\rho},\lambda\right)=h^{*-1}\left(h_i,\tau;\theta,\boldsymbol{\rho},\lambda\right) \tag{29}$$

Similarly, the productivity level determines the unit size.

$$A_j=\tilde{A}\left(h;\boldsymbol{\beta},\delta,\boldsymbol{\rho}\right)=h^{*-1}\left(A_j,Q\left(h\right);\boldsymbol{\beta},\delta,\boldsymbol{\rho}\right) \tag{30}$$

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^* $f_h^*\left(h;\tau,\boldsymbol{\rho},\theta,\lambda,\gamma\right)$m

[32]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.

$g_{h^*}\left(h;\boldsymbol{\beta},\delta,\boldsymbol{\rho}\right)$, from the distribution of income f_Y, and productivity g_A

$$f_{h^*}=\begin{cases} f_Y\left(\tilde{Y}\left(h,\tau\neq 0;\theta,\boldsymbol{\rho},\lambda\right);\gamma\right)\frac{\mathrm{d}}{\mathrm{d}h}\tilde{Y}\left(h,\tau\neq 0;\theta,\boldsymbol{\rho},\lambda\right) & \text{if } h<\underline{h}\left(\boldsymbol{\rho},\lambda\right)\\ \\ f_Y\left(\tilde{Y}\left(h,\tau=0;\theta,\boldsymbol{\rho},\lambda\right);\gamma\right)\frac{\mathrm{d}}{\mathrm{d}h}\tilde{Y}\left(h,\tau=0;\theta,\boldsymbol{\rho},\lambda\right) & \text{if } \underline{h}\left(\boldsymbol{\rho},\lambda\right)<h \end{cases} \tag{31}$$

$$g_{h^*}=\begin{cases} g_A\left(\tilde{A}\left(h;\boldsymbol{\beta},\delta\neq 0,\boldsymbol{\rho}\right)\right)\dfrac{\mathrm{d}\tilde{A}\left(h;\boldsymbol{\beta},\delta\neq 0,\boldsymbol{\rho}\right)}{\mathrm{d}h} & \text{if } h<\underline{h}\left(\boldsymbol{\rho},\lambda\right)\\ \\ g_A\left(\tilde{A}\left(h;\boldsymbol{\beta},\delta=0,\boldsymbol{\rho}\right)\right)\dfrac{\mathrm{d}\tilde{A}\left(h;\boldsymbol{\beta},\delta=0,\boldsymbol{\rho}\right)}{\mathrm{d}h} & \text{if } \underline{h}\left(\boldsymbol{\rho},\lambda\right)<h \end{cases} \tag{32}$$

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, $D_h\left(h;\boldsymbol{\rho},\tau,\theta,\gamma,\lambda\right)$,

$$D_h=\begin{cases} f_{h^*}\left(h;\tau,\boldsymbol{\rho},\theta,\lambda,\gamma\right)\ \mathrm{d}h & \text{if } h<\underline{h}\left(\boldsymbol{\rho},\lambda\right)\\ \\ f_{h^*}\left(\underline{h};\tau,\boldsymbol{\rho},\theta,\lambda,\gamma\right)\ \mathrm{d}h & \\ \qquad\qquad +\int\limits_{\underline{h}}^{\overline{h}} f_{h^*}\left(h;\tau,\boldsymbol{\rho},\theta,\lambda,\gamma\right)\ \mathrm{d}h & \text{if } \underline{h}\left(\boldsymbol{\rho},\lambda\right)=h\\ \\ 0 & \text{if } \underline{h}\left(\boldsymbol{\rho},\lambda\right)<h<\overline{h}\left(\tau,\theta,\boldsymbol{\rho},\lambda\right)\\ \\ f_h^*\left(h;\tau,\boldsymbol{\rho},\theta,\lambda,\gamma\right)\ \mathrm{d}h & \text{if } \overline{h}\left(\tau,\theta,\boldsymbol{\rho},\lambda\right)\leq h \end{cases} \tag{33}$$

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, $Q(h;\alpha)$ allows to get the market level supply density function, $S_h(h, \boldsymbol{\beta}, \delta, \boldsymbol{\rho})$.

$$S_h = \begin{cases} g_{h^*}(h;\boldsymbol{\beta},\delta,\boldsymbol{\rho}) \cdot Q(h;\alpha) & \text{if } h < \underline{h}(\boldsymbol{\rho},\lambda) \\ g_{h^*}(h;\boldsymbol{\beta},\delta,\boldsymbol{\rho}) \cdot Q(h;\alpha) & \\ \qquad + \int_{\underline{h}}^{\overline{h}} g_{h^*}(h;\boldsymbol{\beta},\delta,\boldsymbol{\rho}) \, \mathrm{d}h \cdot Q(h;\alpha) & \text{if } \underline{h}(\boldsymbol{\rho},\lambda) = h \\ 0 & \text{if } \underline{h}(\boldsymbol{\rho},\lambda) < h < \overline{h}(\tau,\theta,\boldsymbol{\rho},\lambda) \\ g_{h^*}(h;\boldsymbol{\beta},\delta,\boldsymbol{\rho}) \, \mathrm{d}h \cdot Q(h;\alpha)(h) & \text{if } \overline{h}(\tau,\theta,\boldsymbol{\rho},\lambda) \leq h \end{cases} \tag{34}$$

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 $P(h;\boldsymbol{\rho})$

$$E = \left\{ P(h;\boldsymbol{\rho}) \in \mathcal{P} : D(h;\tau,\theta,\boldsymbol{\rho},\gamma,\lambda) = S\left(h; A_j,\boldsymbol{\rho},\boldsymbol{\phi}\right) \forall h \in \mathcal{H} \right\} \tag{35}$$

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 13, 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.

Graphical representation

Figure 10b shows the product space or developer density, and figure 10a the exogenous unit supply function. Figure 10c shows an example of the equilibrium density when f_Y follows a log-normal distribution. The equilibrium price makes the product of the top figures match the demand density. The empirical analog of the figure 2 and the equilibrium density are represented in figure 11 for the 2016-2018. Additionally, the figure**??** represents the empirical analog of the figure 10b.The observed density function suggests that the market equilibrium has a discontinuous density and that this stylized model can explain the equilibrium outcomes. Because I standardized all housing units, the differences in housing characteristics disappear and standardized units only vary along a price and size dimension.

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

b. *Density Function* $g_h(h)$

c. $Y \sim$ *log normal* Y

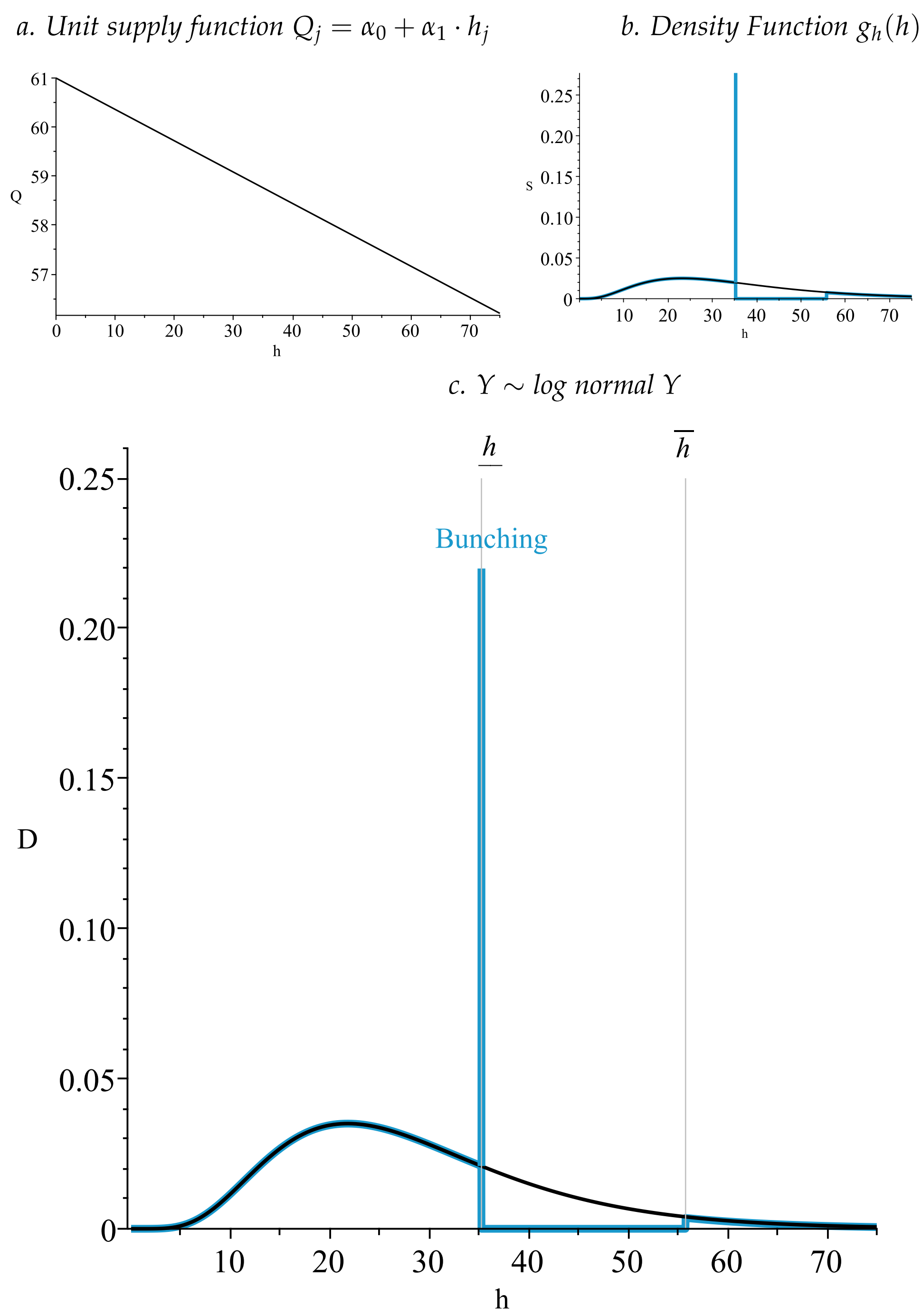


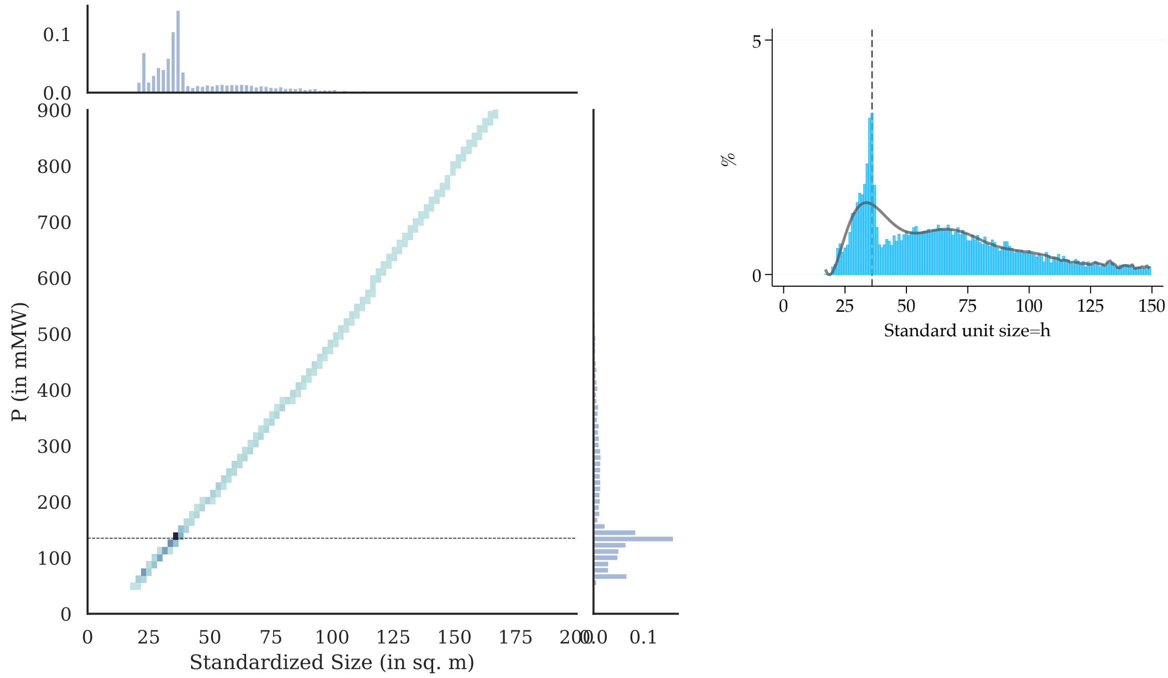
Figure 10: Density by size: Graphical representation

Note:

Empirical analogs

Figure 11: Observed Equilibrium densities and hedonic price 16-18

a. Empirical analog *b. Product space g_h*



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.[33] 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 25 and 26, I recover the marginal buncher household's and developer's conditions:

$$V_d\left(\theta|\underline{h},\overline{h},\boldsymbol{\rho},\tau,\overline{Y}\right) = U\left(\overline{Y} - P\left(\overline{h};\boldsymbol{\rho}\right),\overline{h};\theta\right) - U\left(\overline{Y} - P^{\tau}\left(\underline{h};\boldsymbol{\rho},\tau\right),\underline{h};\theta\right) = 0 \tag{36}$$

$$V_s\left(\beta|\underline{h},\overline{h},\boldsymbol{\rho},\boldsymbol{\alpha},\delta,\overline{A}\right) = \pi\left(Q(\overline{h};\alpha),\overline{A};P\left(\overline{h};\boldsymbol{\rho}\right);\beta\right) - \pi\left(Q(\underline{h};\alpha),\overline{A};P^{\delta}\left(\underline{h};\boldsymbol{\rho},\delta\right);\beta\right) = 0 \tag{37}$$

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 36 and 37. I do not observe $\overline{Y}$ and $\overline{A}$, but I use the optimality conditions in equations 28, 24 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.[34] In contrast to Blomquist et al. (2021) who

[33] 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.
[34]

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.

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	$P = \rho_{0m} + \rho_1 \cdot h + \rho_2 \cdot h^2$
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	$B = A_j \cdot Q \cdot h^{\boldsymbol{\beta}}$

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, $P\left(h|X\right)$. 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 c̊orresponds to the first step. In particular, The policy parameters τ,δ, correspond to the notches presented in figure 2 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: 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				
$\bar{h}$ (developers)	40	53	52	53
$\bar{h}$ (households)	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

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 estimates 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.

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.

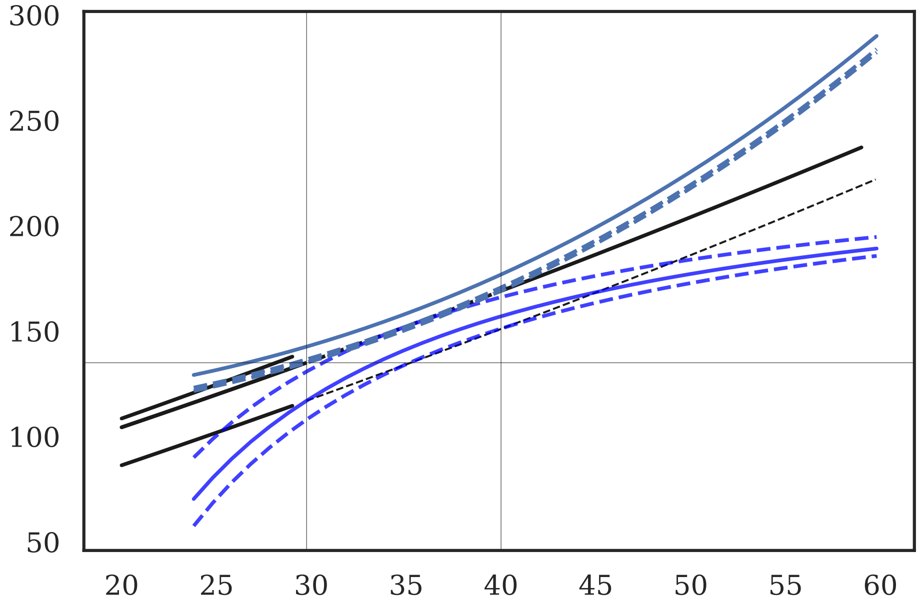
Developers' parameters. On the developer side, the estimated parameter β, changes as the new subsidies are introduced. In the first period beta is 2.53 , this decreases to around 1.7 in the following periods. This change means that the costs of building bigger houses decreased over time.

Benefits and efficiency losses on the demand side

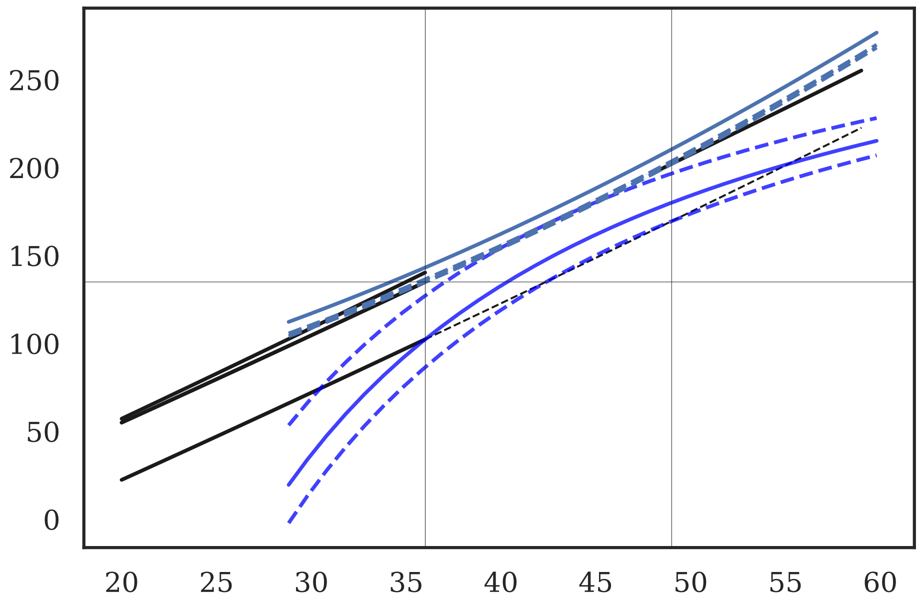
To evaluate the benefits of the subsidy, I focus on the effect on marginally subsidized households. The price limit creates efficiency losses if, like I am assuming, the response on the supply side is a reduction in price and housing size. Figure 12 Illustrates how a representative marginally subsidized 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 12: Representation of the marginally subsidized households and developers



06-08



16-18

NOTE:

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.

Table 6: Counterfactual estimates: Income,Utility Productivity, Marginal Costs and Profits.

	Households			
	06-08	09-11	12-15	16-18
$\underline{Y}$	215.7	324.0	275.6	291.5
Y_{h^*}	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
A_{h^*}	0.0054	0.23	0.17	0.22
$\overline{A}$	0.0045	0.21	0.15	0.20
$\underline{A}$	0.0068	0.26	0.19	0.25
$MgC\left(\underline{h}, Q(\underline{h}), A_*\right)$	219.0	59.0	404.4	161.2
$MgC\left(h^*, Q(h^*), A_*\right)$	172.4	53.7	356.0	144.9
$MgC\left(\underline{h}, Q(\underline{h}), \underline{A}\right)$	223.4	58.6	410.6	161.7
$MgC\left(\overline{h}, Q(\overline{h}), \overline{A}\right)$	214.4	59.5	398.2	160.7
$\pi\left(Q(h^*), A_*; P\left(h^*\right)\right)$	7326.4	359.9	4359.1	1266.4
$\pi\left(Q(h^*, A_*; P^{\delta}\left(h^*\right)\right)$	7740.0	439.8	4889.1	1478.6
$\pi\left(Q(\underline{h}), A_*; P\left(\underline{h}\right)\right)$	7218.6	341.6	4234.4	1217.2
$\pi\left(Q(h^*), A_*; P^{\delta}\left(\underline{h}\right)\right)$	7588.2	406.1	4668.9	1388.9
$\pi\left(Q(\overline{h}), \overline{A}; P\left(\overline{h}\right)\right)$	7930.5	512.2	5262.2	1646.0
$\pi\left(Q(\underline{h}), \underline{A}; P\left(\underline{h}\right)\right)$	6725.5	205.8	3449.4	881.6

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, 12 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.[35] Moreover this is an important policy debate, in Colombia the construction sector argues that eliminating the housing subsidies will create a rationing problem.[36]

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 13 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 13 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.

[35]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)

[36]*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)

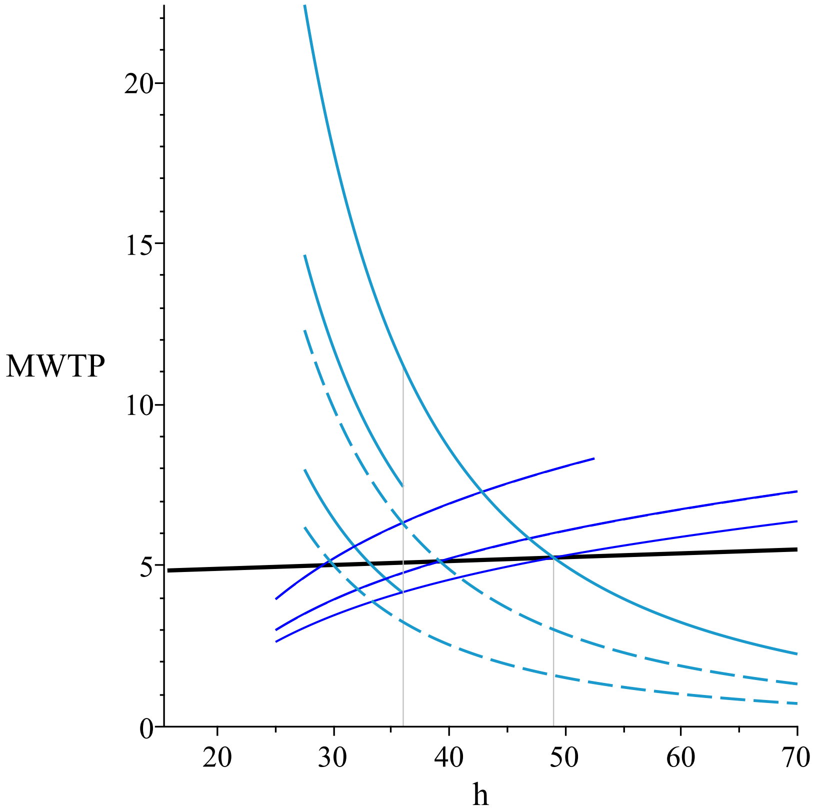


Figure 13: Demand, supply function and marginal equilibrium implicit price

VII. Conclusions

Main takeaways

Open questions and remaining challenges

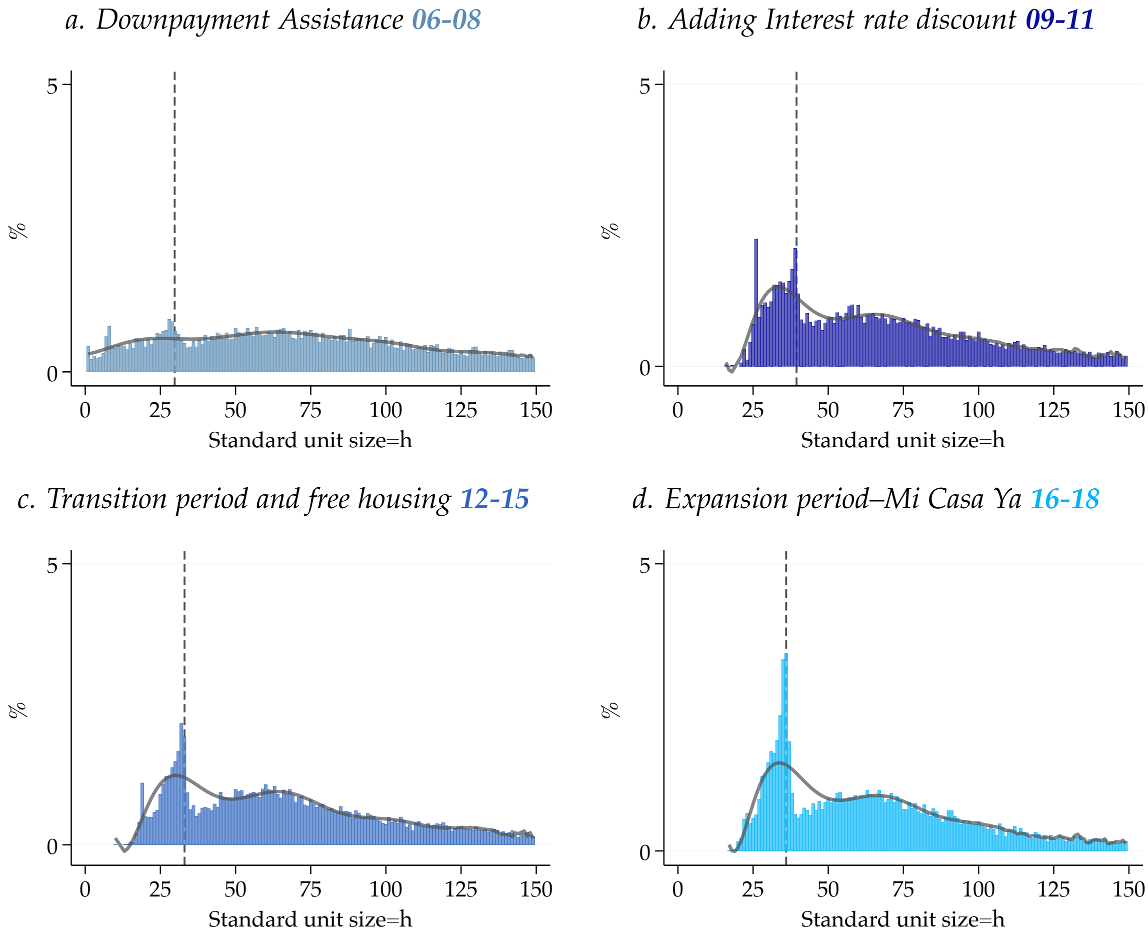
- How does the new housing affect the housing market? (i.e. Does it affect the prices of the existing housing stock?)
- employment effects and stimulus effect.
- What is the role of banks
- What are the difference between interest rate subsidy and mortgage deduction subsidy. Does it matter.

I. Appendix

NEED TO WORK ON THESE

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
Behavioural Responses				
$\int_{h_{min}}^{\underline{h}^{-}} T(h)\mathrm{d}h$	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
$g(\underline{h})$	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

A. Model Appendix:

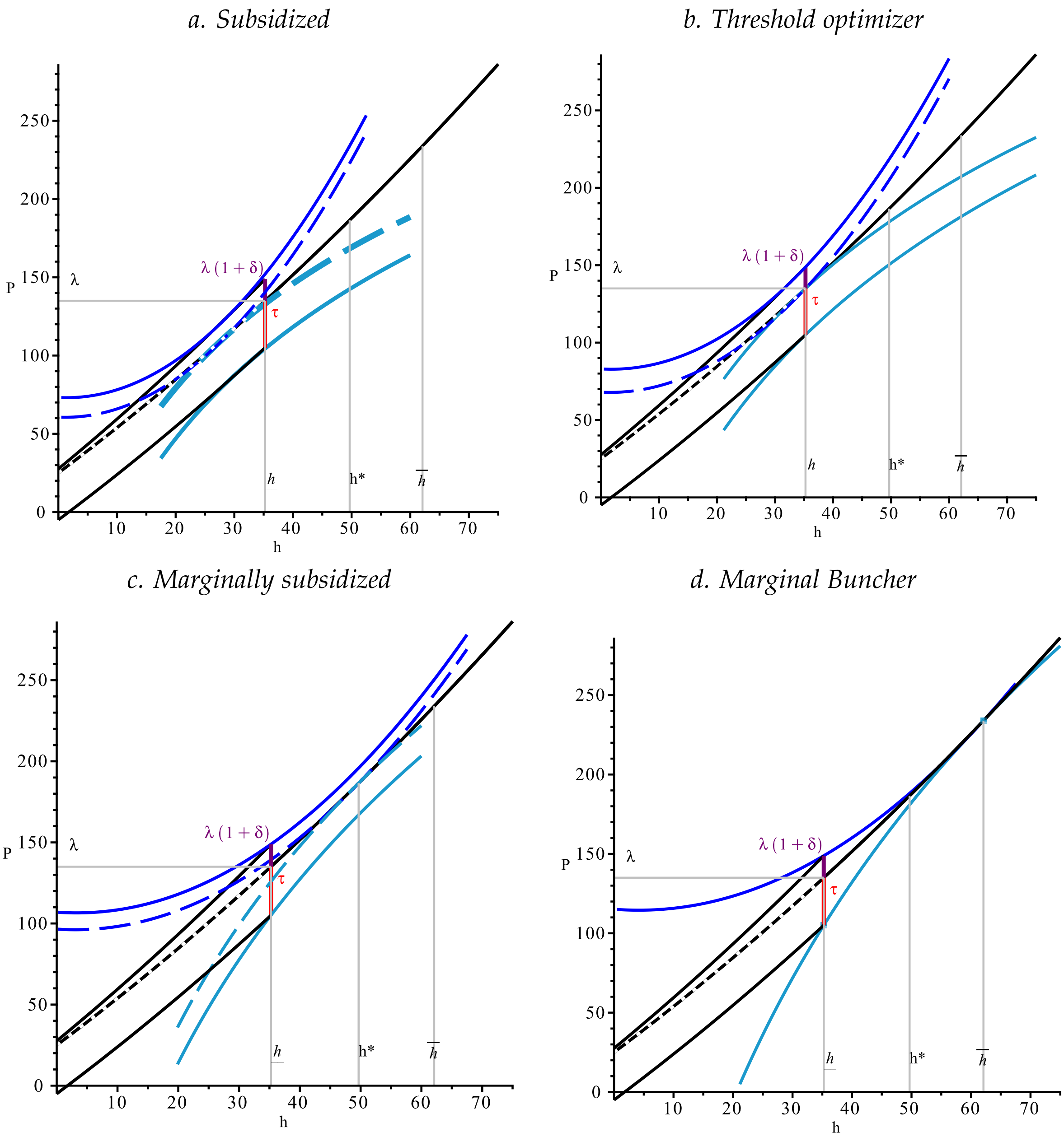


Figure A- 2: Graphical representation of equilibrium choices

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 $Q(h) = \frac{\alpha}{h^2}$

II. Colombian Housing Policy: Additional Details

The Demand 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.[37] 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 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 **??** in the appendix presents more details about this subsidy.

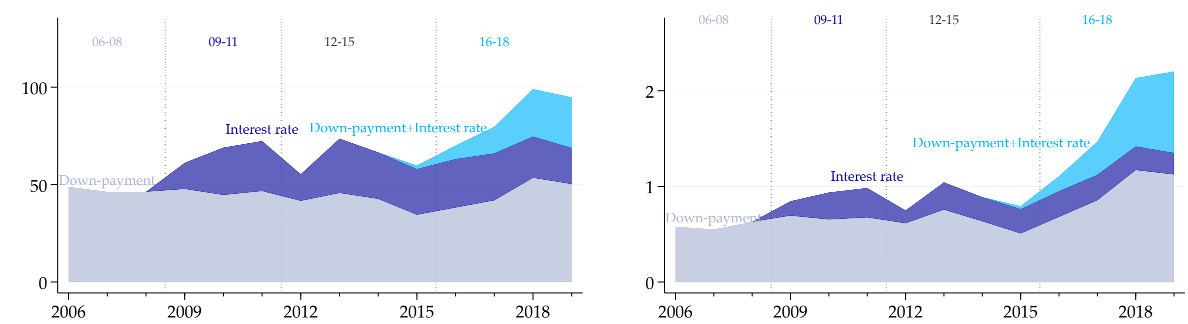
The subsidy expansion–Mi casa ya. In 2015, the government doubled the effort and introduced a new program *Mi casa ya*, (my house now). Before this program was introduced, the down payment subsidy was only available to formal employees-contributing to the family compensation funds.[38] This program extended the cover-

[37]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.

[38]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

age 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.

a. Total # of Subsidies *b. Total Government Expenditure*



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.[39] 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.[40] 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.

populations are displaced by armed conflict and affected by natural disasters. I include the equivalent plots for those subsidies in the appendix.

[39]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.

[40]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.

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 households. The appendix figure **??** shows the evolution of those subsidies.[41] 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.

[41]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.

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