Equilibrium Effects of Housing Subsidies: Evidence from a Policy Notch in Colombia

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Are Market-Oriented Housing Policies Effective?

- Governments implement various **market-oriented** policies to promote housing construction and home-ownership.
  - Subsidies or tax incentives

Questions:

1. Housing market effect?
   - Prices, quantities, **type of housing**
2. Does incentivizing home-ownership work?
   - Are there any unintended consequences?
   - What happens if these policies are removed?
   - How big are the efficiency costs?

- I use a quasi-experiment to estimate a housing market model.
- Counterfactual policy evaluation and welfare analysis.

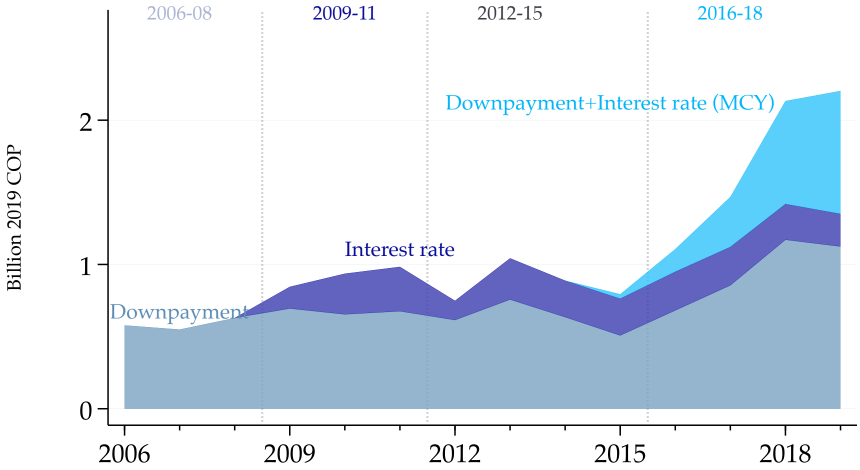
Colombian Housing Policy

- Policy tools:
  1. Subsidies to low-income households low-cost housing.
  2. Tax incentives to developers who build low-cost housing.
  3. A **price cap** defining low-cost housing.

     135 monthly minimum wages (mMW) $\approx 40,000 \ \$USD$

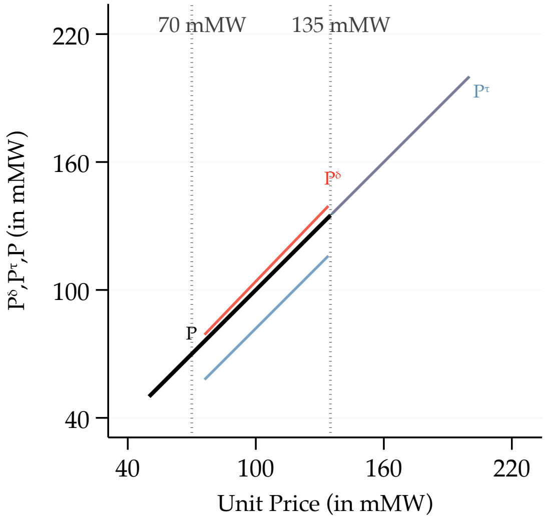
- Empirical advantages:
  1. Price cap
     - Discontinuous incentives for developers and households to bunch at the cutoff.
  2. Unique and novel data
     - Census data for all new construction projects.
     - Administrative records for the subsidies.
  3. Subsidy expansion (2006-18)

Government Expenditure and Policy Expansion



- Four different periods of expansion
  - 2006-08: Downpayment (only for formal employees)
  - 2009-11: + Interest rate subsidy
  - 2012-15: Focus on extremely poor population (subsidies targeted at 70*mMW*)
  - 2016-18: + *Mi Casa Ya–MCY* (downpayment **and** interest for informal and formal employees)

THE NOTCH



Transaction Price

P

Developers Price

$\mathbf{P}^{\delta} = P \cdot (1 + \delta)$:

δ =Tax refund

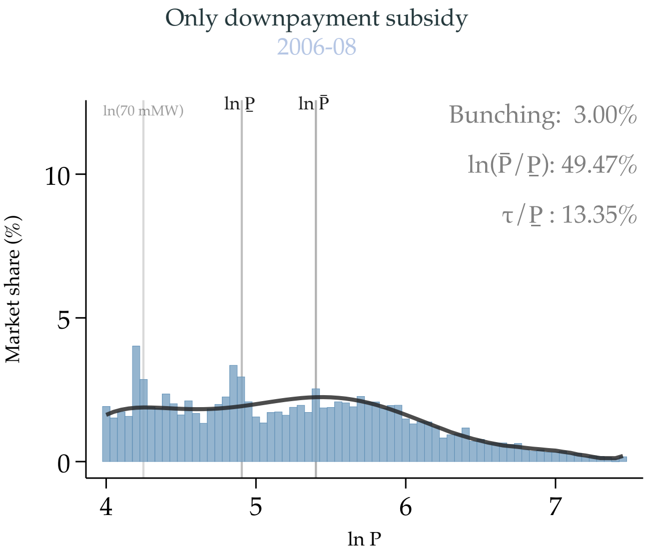
Households price

$\mathbf{P}^{\tau} = P - \tau$

τ =Subsidy

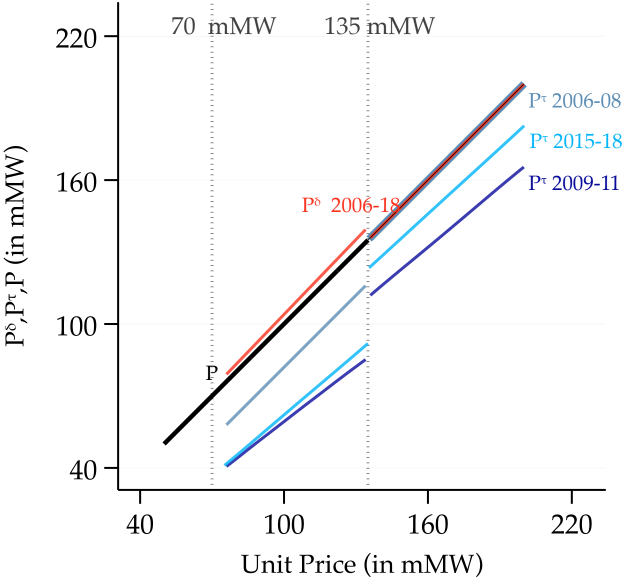
Agents benefit from buying/selling *low cost housing* ($P \leq 135mMW$)

Bunching at the Low-Cost Housing Price Limit



Bunching estimation details

The Demand Notch Increases Over Time



Supply Notch δ

2006-18 4%

Demand Notch τ_t

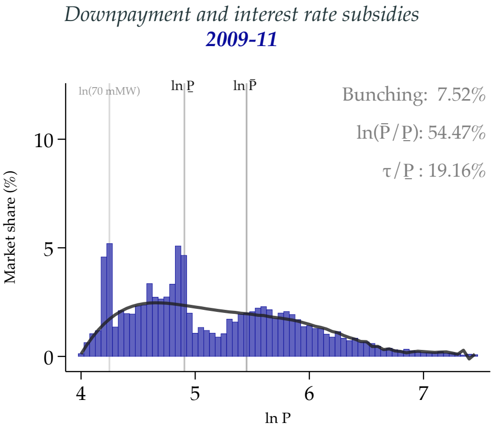
2006-08: 18 *mMW*

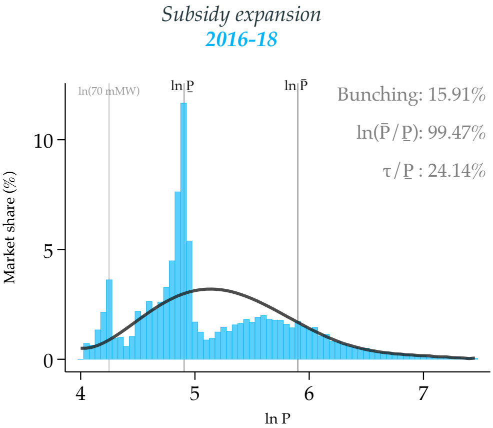
2009-11: 26 *mMW*

2016-18: 33 *mMW*

Note: 2012-15 Too many changes and free housing at 70 *mMW*

Larger Bunching as Notch Increases





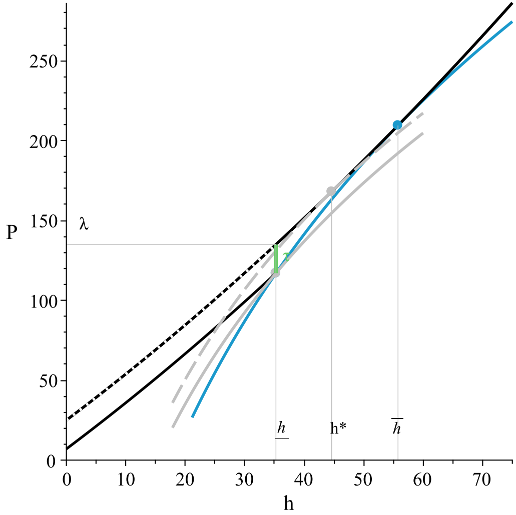
- Changes in unit size
- Why size?
  - Continuous, easy to measure, monotonic relationship with price and income.
  - In contrast to most datasets, I observe it.

II. Equilibrium Model of Housing Supply and Demand

Housing Market Equilibrium Model

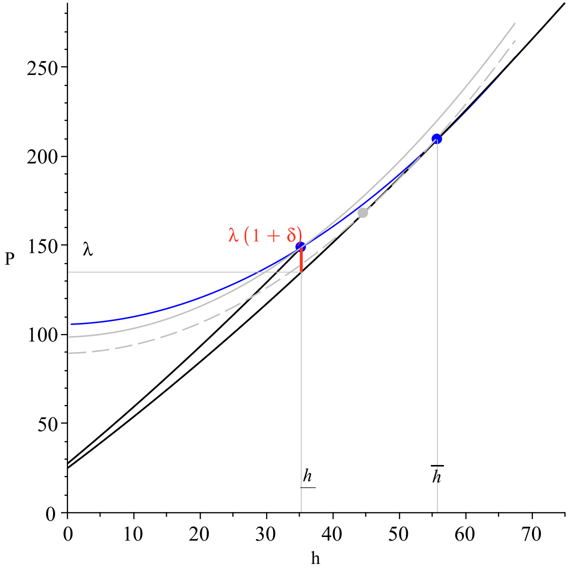
1. **Housing**
    - Differentiated product described by its size $h \in \mathcal{H}$
    - Price depends on size $P(h)$
2. **Households** $i \in I$, Heterogeneous in Income $Y_i \sim F_Y$
    - Choose h_i and consumption C_i to maximize Utility $U(C_i, h_i; \theta)$
3. **Developers** $j \in J$, Heterogeneous in Productivity $A_j \sim G_A$
    - Choose h_j to maximize profits
    - Building costs $B(A_j, h_j, Q\left(h_j\right); \beta)$
4. **Competitive Market Equilibrium**
    - Price function $P\left(h\right) \rightarrow$ clears the market $\forall h \in \mathcal{H}$

Households' Optimal Choices



- **Implicit Price Function**
  $P(h)$
- **Subsidy**
  τ
- **Bid functions**
  $\varphi_D\left(h, Y, \bar{U}; \theta\right)$
  - $\bar{U} = U\left(h, Y_i - \varphi_D; \theta\right)$
  - $\bar{U}_\tau = U\left(h, Y_i - \varphi_D + \tau; \theta\right)$

Developers' Optimal Choices



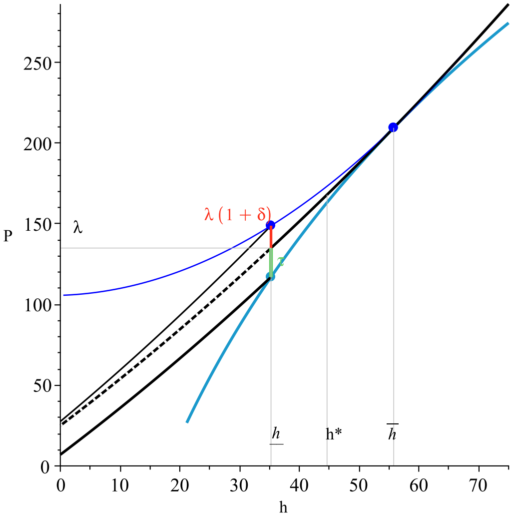
- **Implicit Price Function**
  $P(h)$

- **Tax incentives**
  $P(h) \cdot (1+\delta)$

- **Offer Functions**
  $\varphi_S\left(h, A_j, \bar{\pi}; \beta\right)$

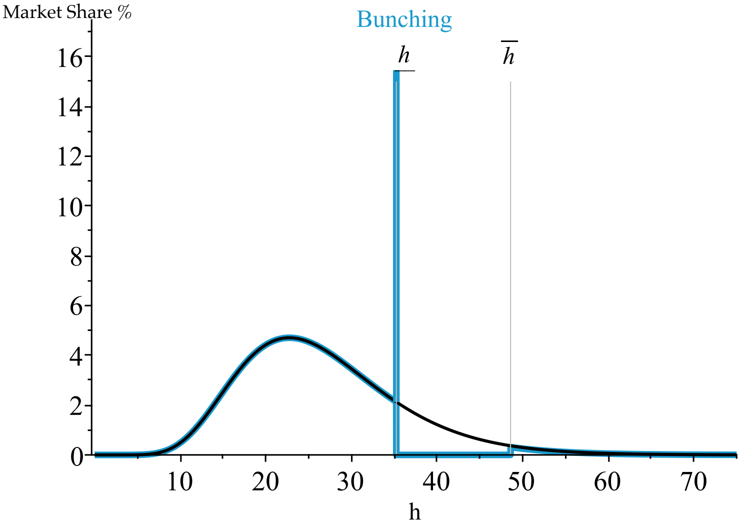
$$\bar{\pi} = \pi\left(h, A_j, P\left(h\right); \boldsymbol{\beta}\right)$$
$$\bar{\pi}_\delta = \pi\left(h, A_j, P\left(h\right) * \left(1+\delta\right)\right); \boldsymbol{\beta}\right)$$

Equilibrium Choices: Developers and Households Match



Implicit price: Envelop of offer and bid curves.

Aggregate Equilibrium Density



How to aggregate? → Change of variable formula optimal choices (h^*) and the details

Identification

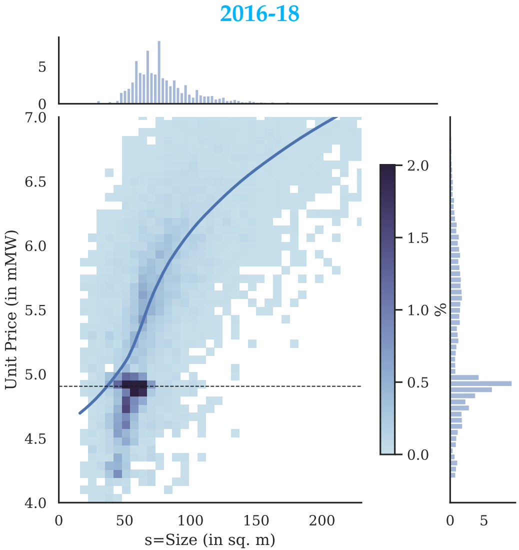
Marginal Buncher Condition

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	
Utility	$U = \left[\frac{1}{2} \cdot C^{\theta} + \frac{1}{2} \cdot h^{\theta}\right]^{\frac{1}{\theta}}$
Cost	$B = A_j \cdot Q \cdot h^{\boldsymbol{\beta}}$

details

ESTIMATION

Observed Equilibrium: Prices, Quantities, and Size



- Solid line: price vs size
  → hedonic price function

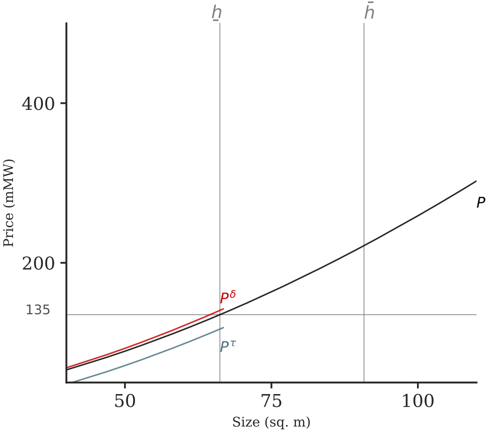
- Multiple characteristics
  → Reduce to a single characteristic

- Standard unit size (h):
  → Size of a unit with average characteristics that costs the same price

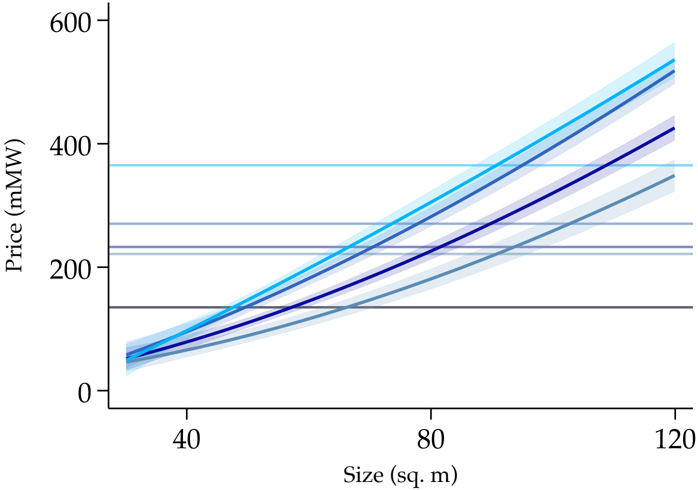
details

STEP I: EQUILIBRIUM CHARACTERIZATION

- Using the observed hedonic equilibrium
  - Price function: $P(h)$
  - Size threshold: $\underline{h} = P^{-1}$ ($\lambda = 135mMW$)
  - Standard Unit Size: h
- Behavioural Responses:
  - Housing size for marginal buncher: $\overline{h}$
- Unit Supply Function:
  - $Q = \alpha_0 + \alpha_1 \cdot h_{ltc}$ see
- Policy Parameters:
  - Notches: τ_t,δ see



Implicit Prices for Housing Size Over Time



Structural Parameters, Inefficiencies and Counterfactual Policies

Table 1: Structural parameters

	06-08	09-11	12-15	16-18
β	2.34	2.03	1.65	1.29
θ	0.55	0.40	0.55	0.74
σ	2.23	1.68	2.22	3.88

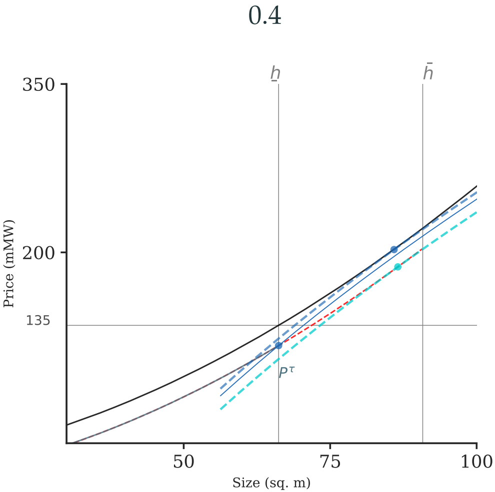
1. Same households get subsidy but they can buy any house.
   - Question: How much better off households are?
2. Policy proposal: Remove the tax incentives to developers
   - Developers reaction:

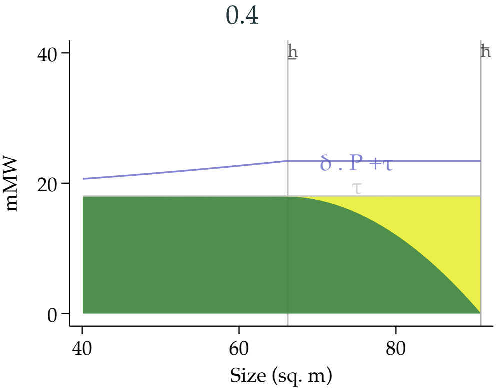
     "If these items are repealed, in Valle del Cauca we would go from having an offer of SH and sales of 23,000 homes, average year, to one of sales of 4,600 homes"

     source: El Tiempo (2021)
   - Question: What happens to the marginally subsidized developers?

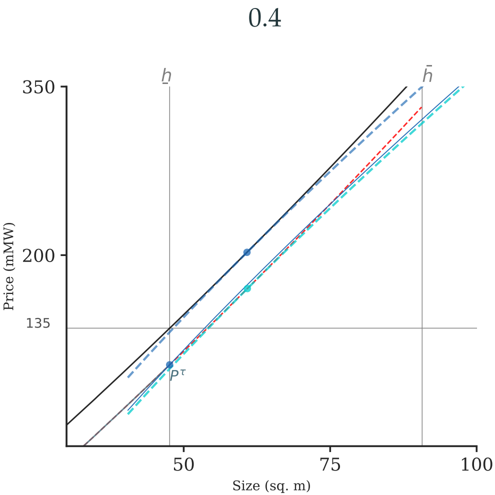
EFFECT ON MARGINALLY SUBSIDIZED HOUSEHOLDS

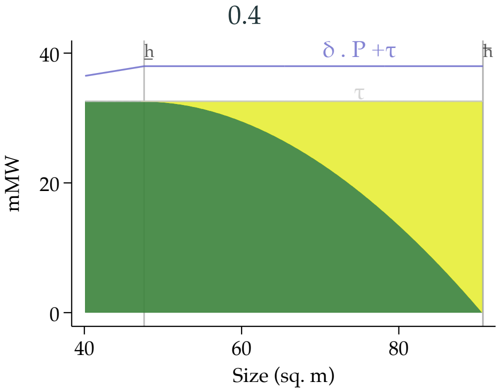
2006-08





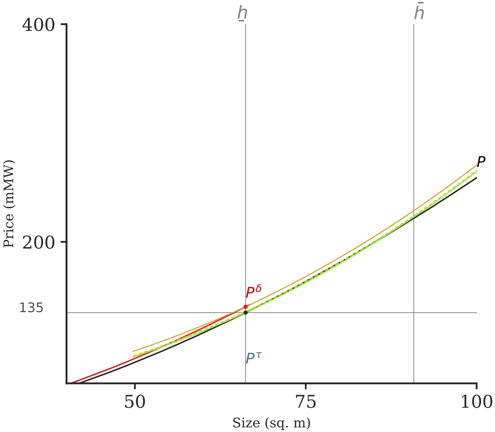
EFFECT ON MARGINALLY SUBSIDIZED HOUSEHOLDS **2016-18**

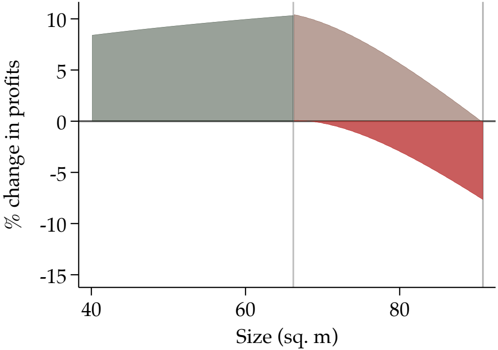




Developer Response to Tax Incentives

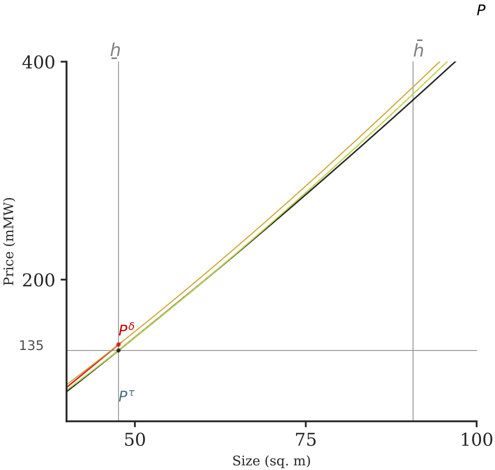
2006-08

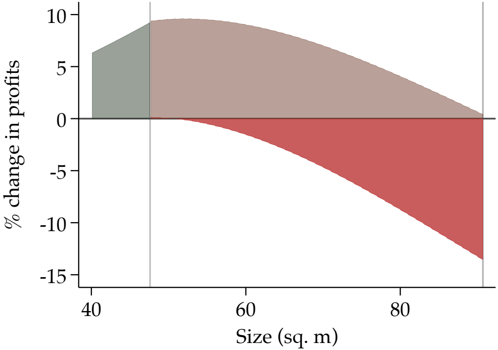




Developer Response to Tax Incentives

2016-18





Literature and Contribution

Integrates the ***bunching*** and ***hedonic*** literatures to propose a method to think about welfare consequences of ***housing policies***

Bunching	**Hedonic**	**Housing Policy**
▶ Housing market	▶ Policy notch	▶ Evidence
▶ Link to model	▶ Supply side	▶ Welfare
▶ Supply and demand	▶ Identification	▶ Counterfactuals

Bunching

- Housing market applications
  Best et al. (2019), DeFusco and Paciorek (2017)
- Methodology
  Notches >> *Kinks*:
  Kleven (2016), Bertanha et al. (2021), Blomquist et al. (2021)

Hedonic

- Seminal paper
  Rosen (1974),Epple (1987)
- Recent Contributions
  Bajari and Benkard (2005), Heckman et al. (2010), Epple et al. (2020), Chernozhukov et al. (2021)
- Reviews
  Kuminoff et al. (2013), Greenstone (2017)

Housing Policy

- Developers subsidies
  Baum-Snow and Marion (2009), Soltas (2021), Sinai and Waldfogel (2005)
- Households Subsidies
  Carozzi et al. (2020)
- Incidence and welfare
  Poterba (1992), Galiani et al. (2015)

Conclusion (I): The paper

- Characterization of the equilibrium.
- Compelling evidence of the market responding to subsidies.
- An hedonic housing market equilibrium with heterogeneous agents can rationalize the response.
- Propose a identification strategy to recover the model parameters.
- Model+estimates $\rightarrow$ Welfare.
- Policy design matters $\rightarrow$ need to be careful of how agents respond to incentives.

Conclusion (II): Generalization

- The method I propose could be used to evaluate housing policy more generally.
- Two facts suggest this could be potentially effective.
  1. There is increasing evidence to bunching responses to nonlinear incentives (e.g., help to buy, housing programs in the USA)
  2. Many other sources of non linear incentives in housing markets.
- Further, it can be applied to other markets (e.g., labor markets, drugs, etc.)

Appendix

Research Agenda

- In my research I exploit natural experiments using administrative and census data to study the impacts of large scales government investments.
  - What are effects on the population?
  - Are there any unintended consequences?
  - How do we evaluate costs?
  - What are the welfare effects?
  - How should we target subsidies?
  - Should governments invest directly or through subsidies?
  - Can we be more efficient in the way we spend the money?
- In my current projects I address these questions by studying subsidies to utilities, a push in internet expansion, the construction of the US interstate highway system and housing subsidies.

Current Projects

- Does the US have an Infrastructure Cost Problem? Evidence from the Interstate Highway System (2021)
  with *Neil Mehrotra* and *Matthew A. Turner*

- The Effect of Location-Based Subsidies on the Housing Market (2021)

- Internet Expansion and School Performance: Evidence from Colombia (2021)
  with *Aaron Weisbrod*

- The Expansion of Higher Education in Colombia: Bad Students or Bad Programs? (2021)
  with *Adriana Camacho* and *Julian Messina*

WHAT'S NEXT?

I want to keep finding setting to explore these questions and propose methods to evaluate the effects of government expenditures.

- Focus on housing subsidies
  - Study different policy approaches
  - Keep exploring the role of supply
  - Financial sector and inter-temporal decisions
  - Effects of housing policies on the labor market and other sectors
- Effects of highways or other policies like the *estratos* on urban shape and segregation patterns.

References

Bajari, P., & Benkard, C. L. (2005). Demand estimation with heterogeneous consumers and unobserved product characteristics: A hedonic approach. *Journal of Political Economy*, *113*(6), 1239-1276. link

Baum-Snow, N., & Marion, J. (2009). The effects of low income housing tax credit developments on neighborhoods. *Journal of Public Economics*, *93*(5), 654 - 666. link

Bertanha, M., McCallum, A. H., & Seegert, N. (2021). *Better bunching, nicer notching.* link

Best, M. C., Cloyne, J. S., Ilzetzki, E., & Kleven, H. J. (2019, 05). Estimating the Elasticity of Intertemporal Substitution Using Mortgage Notches. *The Review of Economic Studies*, *87*(2), 656-690. link

Bishop, K. C., & Timmins, C. (2019). Estimating the marginal willingness to pay function without instrumental variables. *Journal of Urban Economics*, *109*, 66-83. link

Blomquist, S., Newey, W. K., Kumar, A., & Liang, C.-Y. (2021). On bunching and identification of the taxable income elasticity. *Journal of Political Economy*, *129*(8), 000–000.

Carozzi, F., Hilber, C., & Yu, X. (2020). *On the economic impacts of mortgage credit expansion policies: Evidence from help to buy* [CEP Discussion Paper No 1681]. link

Chernozhukov, V., Galichon, A., Henry, M., & Pass, B. (2021). *Identification of hedonic equilibrium and nonseparable simultaneous equations.*

DeFusco, A. A., & Paciorek, A. (2017, February). The interest rate elasticity of mortgage demand: Evidence from bunching at the conforming loan limit. *American Economic Journal: Economic Policy*, *9*(1), 210-40. link

Epple, D. (1987). Hedonic prices and implicit markets: Estimating demand and supply functions for differentiated products. *Journal of Political Economy*, *95*(1), 59-80. link

Epple, D., Quintero, L., & Sieg, H. (2020). A new approach to estimating equilibrium models for metropolitan housing markets. *Journal of Political Economy*, *128*(3), 948-983. link

Galiani, S., Murphy, A., & Pantano, J. (2015, November). Estimating neighborhood choice models: Lessons from a housing assistance experiment. *American Economic Review*, *105*(11), 3385-3415. link

Greenstone, M. (2017). The continuing impact of sherwin rosen's "hedonic prices and implicit markets: Product differentiation in pure competition". *Journal of Political Economy*, *125*(6), 1891-1902. link

Heckman, J. J., Matzkin, R. L., & Nesheim, L. (2010). Nonparametric identification and estimation of nonadditive hedonic models. *Econometrica*, *78*(5), 1569-1591. link

Kleven, H. J. (2016). Bunching. *Annual Review of Economics*, *8*(1), 435-464. link

Kuminoff, N. V., Smith, V. K., & Timmins, C. (2013, December). The new economics of equilibrium sorting and policy evaluation using housing markets. *Journal of Economic Literature*, *51*(4), 1007-62. link

Poterba, J. M. (1984, 11). Tax Subsidies to Owner-Occupied Housing: An Asset-Market Approach*. *The Quarterly Journal of Economics*, *99*(4), 729-752. link

Poterba, J. M. (1992). Taxation and housing: Old questions, new answers. *The American Economic Review*, *82*(2), 237–242. link

Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy*, *82*(1), 34-55. link

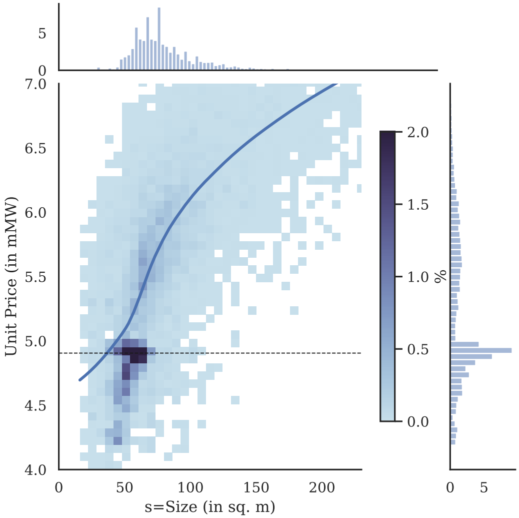
Sinai, T., & Waldfogel, J. (2005). Do low-income housing subsidies increase the occupied housing stock? *Journal of Public Economics*, *89*(11), 2137 - 2164. link

Soltas, E. (2021). The price of inclusion: Evidence from housing developer behavior.. link

From size s to Standardized Size h

Subsidy expansion **2016-18**

Observed size



Standardized Unit

Chap_1/Figures/Equilibrium_All_share

Hedonic Prices

- Hedonic price/Implicit price for housing size

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

l, house type in a development, t year, c city

  - Simplifying assumption: $\rho\left(s_{ltc}\right) = \rho_1 \cdot s_{ltc} + \rho_2 \cdot {s^2}_{ltc}$
  - Identifying assumption: $\mathrm{E}\left(s_{ltc} | X_{ltc}, \omega_{ltc}\right) = 0$

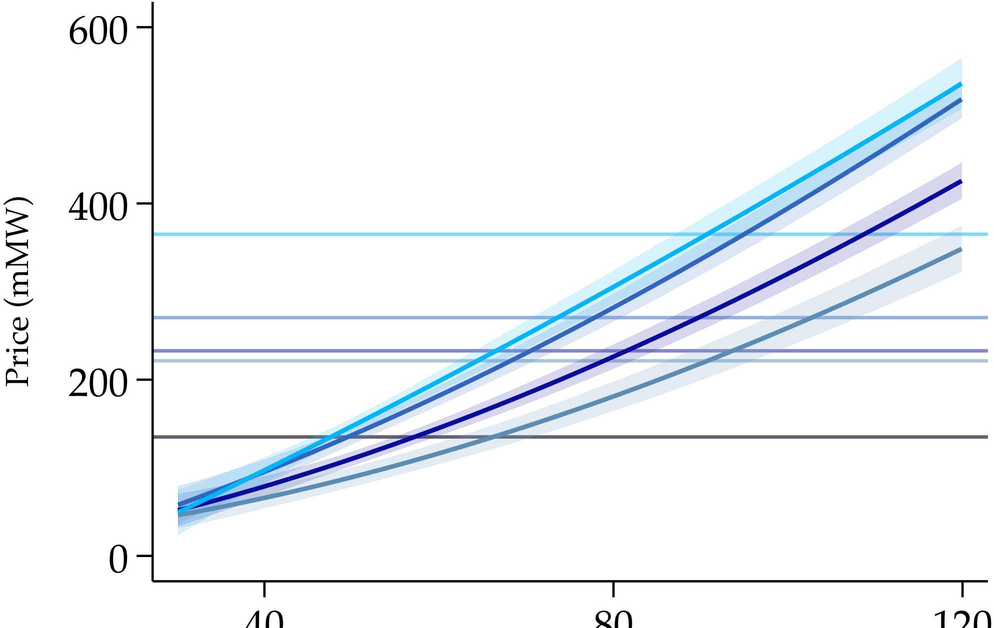
- Standard Unit Size h_{ltc}

$$\rho\left(h_{ltc}\right) + \Gamma' \bar{X} + \bar{\omega} = \rho\left(s_{ltc}\right) + \Gamma' X_{ltc} + \omega_{ltc} \tag{2}$$

  - Characteristics of the standard house: $\bar{X}$, $\bar{\omega}$

figures

Implicit Prices for Housing Size Over Time



Behavioural Responses Induced by the Policy

- Recovered by comparing observed and counterfactual distribution

Observed $f_{h^*} \rightarrow$ histogram

Counterfactual $f_{h_0} \rightarrow$ predicted density excluding observations around the cutoff (Kleven, 2016)

$$h_b = \sum_{p=0}^{T} \hat{\iota}_p h_b^p + \sum_{k=L}^{H} \kappa_k \cdot \mathbb{1}\left[h_k = h_b\right] + v_b$$

$$\hat{f}_{h_0} = \sum_{p=0}^{T} \hat{\iota}_p h_b^p$$

Choice parameters: bin size, bounds for excluded area (L,H) and polynomial degree p

Figures

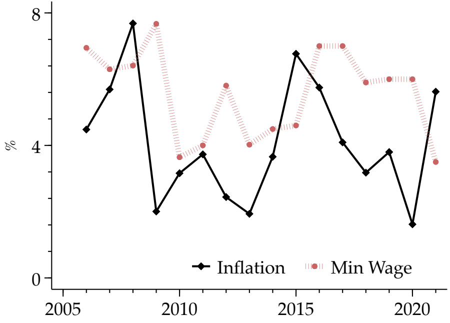
Equilibrium: Developers Aggregate Supply Density

$$D(h) = \begin{cases} f_{h^*}(h)\,\mathrm{d}h & \text{if } h < \underline{h} \\ f_{h^*}(h)\,\mathrm{d}h \\ \qquad + \int_{\underline{h}}^{\overline{h}} f_{h^*}(h)\,\mathrm{d}h & \text{if } \underline{h} = h \\ 0 & \text{if } h \in \left(\underline{h}, \overline{h}\right) \\ f_h^*(h)\,\mathrm{d}h & \text{if } \overline{h} \le h \end{cases}$$

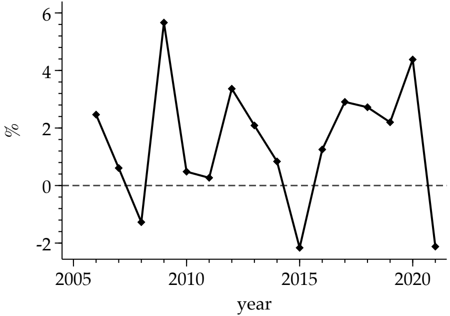
$$S(h) = \begin{cases} g_{h^*}(h) \cdot Q(h) & \text{if } h < \underline{h} \\ \left(g_{\underline{h}^*}(\underline{h}) + \int_{\underline{h}}^{\overline{h}} g_{h^*}(h)\ \mathrm{d}h\right) \cdot Q(\underline{h}) & \text{if } \underline{h} = h \\ 0 & \text{if } \underline{h} < h < \overline{h} \\ g_{h^*} \cdot Q(h) & \text{if } \overline{h} \le h \end{cases}$$

Equilibrium Figures

Inflation and minimum wages.



a. Min wage and Inflation

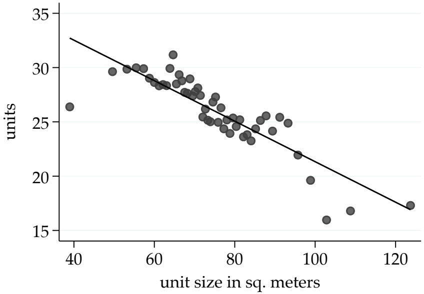


b. Min wage and Inflation

Data

DEVELOPERS CHOICES OF SIZE AND UNIT SUPPLY

All data



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

	06-08	09-11	12-15	16-18
[illegible]	70.5	12.7	81.1	[illegible]

Product type density (g_h)

2006-08

Chap_1/Figures//Distribution_st_

2016-18

Notches

- Demand Notch Overtime

	Notch *(in mMW)*			# Subsidies *(in thousand)*		
	τ^M	τ^i	τ	*down payment*	*i rate*	*Mi Casa Ya*
2006-08	18.0	.	18.0	47.1	.	.
2009-11	20.0	5.85	25.9	46.4	16.7	.
2012-15	19.9	9.55	29.5	41.1	22.2	.
2016-18	25.3	7.24	32.6	44.5	23.4	16.8

- Supply Notch: 4 percent

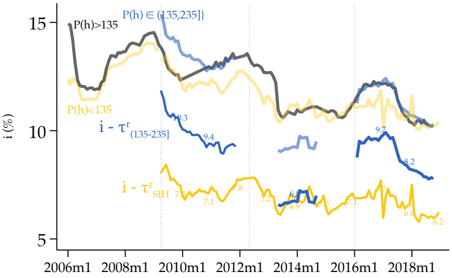
Step I

Data: Mortgages and Interest Rates

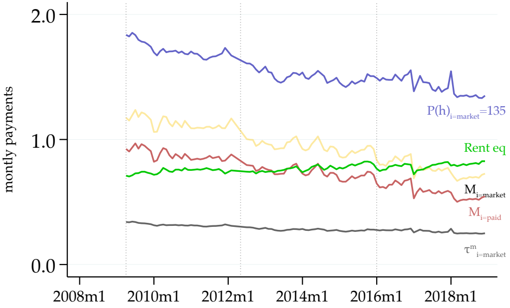
rent equivalent ((Poterba, 1984), (Bishop & Timmins, 2019) assume it is 0.05)

- Size of the mortgages and interest rate.
- Identifier for SIH.

Market interest rate i and subsidy τ^r



Monthly payments and monthly equivalent for relevant values. $P(h) < 135$



- To convert the magnitudes into monthly payments I use:

$$X_{montly} = X \cdot \kappa(i,n)\,;\,\kappa(i,n) = \frac{\frac{i}{12}\cdot\left(1+\frac{i}{12}\right)^{12\cdot n}}{\left(1+\frac{i}{12}\right)^{n\cdot 12}-1}$$

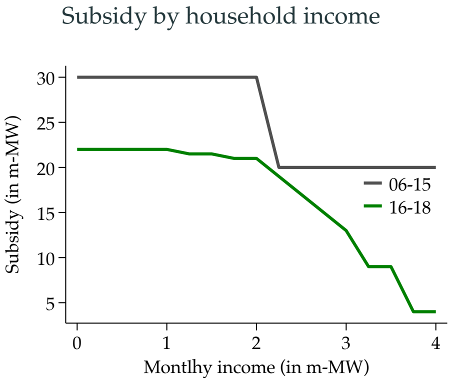
Households' Demand Function

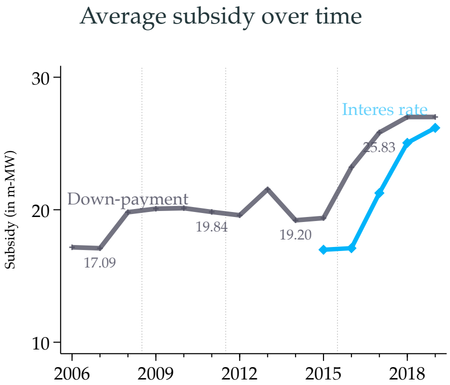
$$h^{\mathrm{D}}\left(Y_i\right)=\begin{cases} h^*\left(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda\right) & \text{if } Y_i\leq \underline{Y} \\ \underline{h} & \text{if } \underline{Y}<Y_i<\overline{Y} \\ h^*\left(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda\right) & \text{if } \overline{Y}\leq Y_i \end{cases}$$

- Tangency conditions: $h^*\left(Y_i,\tau;\theta,\boldsymbol{\rho},\lambda\right)$
- Income and unit size: $Y_i=\tilde{Y}\left(h,\tau;\theta,\boldsymbol{\rho},\lambda\right)=h^{*-1}\left(h_i,\tau;\theta,\boldsymbol{\rho},\lambda\right)$

Graphs

The Notch: Down Payment Subsidy



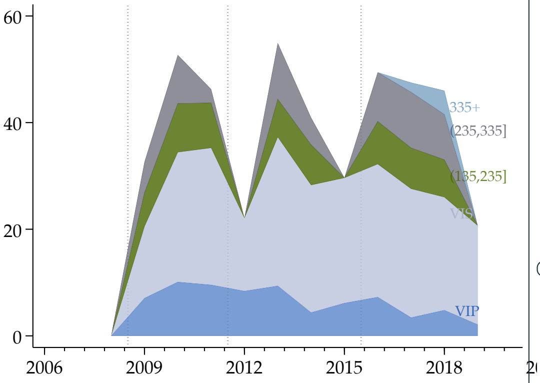


- Varies by income.
- Increase in 2016.
- Expanded trough *mi casa YA*

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

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

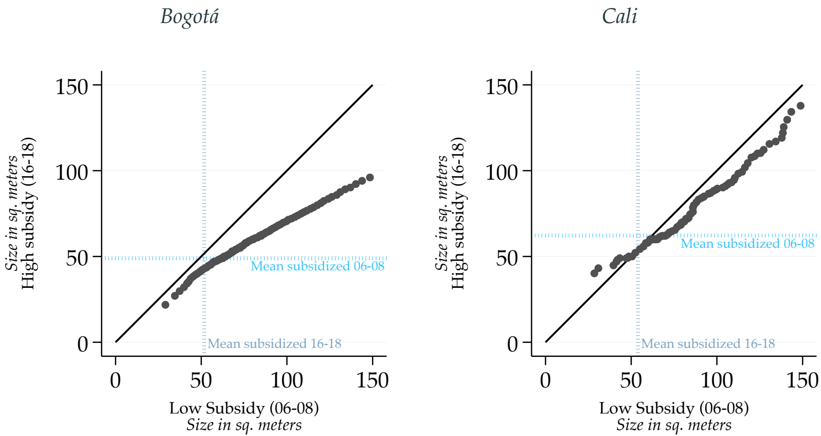
a. Total # of subsidies



b. Total amount of subsidies

Chap_1/Figures/FRECH_subsidy_COP_cpi

Changes in Housing Stock Characteristics



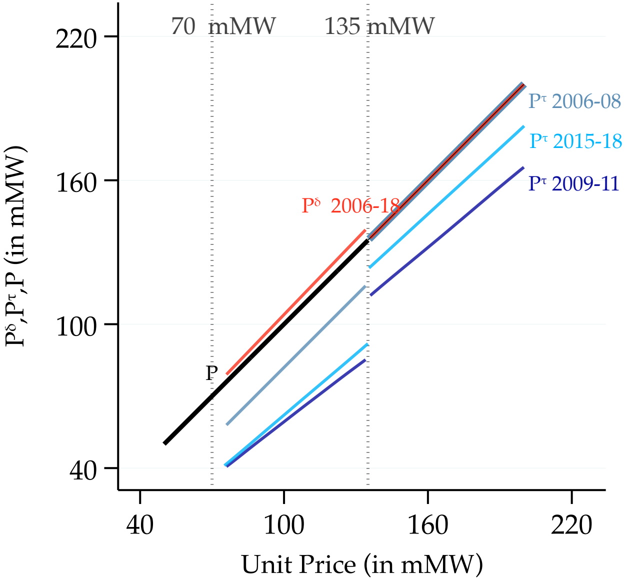
Bunching

Prices

Chap_1/Figures/Price_function_All_main.pdf

Chap_1/Figures/M/1st_step.pdf

The Demand Notch Increases Over Time



Supply Notch δ

2006-18 4%

Demand Notch τ_t

2006-08: 19.7 mMW

2009-11: 26.4 mMW

2016-18: 33.1 mMW

2012-15 Too many changes and free housing at 70mMW

Alternative Representation of the Equilibrium. Demand and Supply for Size

Expansion period Mi Casa Ya **2016-18**

Chap_1/Figures/MgFigure_period_16-18.pdf

EFFECT ON MARGINALLY SUBSIDIZED DEVELOPERS

2006-08

Chap_1/Figures/welfare_supply_period_06-08.pdf

2016-18

Chap_1/Figures/welfare_supply_period

Changes in profits (%)

Effect on Marginally Subsidized Households

2006-08

Chap_1/Figures/welfare_demand_period_06-08.pdf

2009-11

Chap_1/Figures/welfare_demand_period

Equations

Optimality Conditions	
Income	$\overline{Y} = (2\cdot h\cdot\rho_2+\rho_1)^{-\frac{1}{\theta-1}}\cdot h + h^2\cdot\rho_2 + h\cdot\rho_1+\rho_0$
Productivity	$\overline{A} = \frac{3\cdot(\delta+1)\cdot(h\cdot\alpha_1+\alpha_0)\cdot\left(\left(h^2\cdot\rho_2+\frac{2}{3}\cdot h\cdot\rho_1+\frac{1}{3}\cdot\rho_0\right)\cdot\alpha_1+\frac{2\cdot\left(h\cdot\rho_2+\frac{\rho_1}{2}\right)\cdot\alpha_0}{3}\right)}{h^{\boldsymbol{\beta}+1}\cdot\alpha_1^2+h^{\boldsymbol{\beta}}\cdot\alpha_0\cdot\alpha_1+2\cdot h\cdot(h\cdot\alpha_1+\alpha_0)^2}$
Marginal Buncher Condition	
Household	$0 = \left(\frac{\underline{h}^{\theta}+\left(\bar{h}^2\rho_2-\rho_2\underline{h}^2+\bar{h}\rho_1+\bar{h}\left(2\bar{h}\rho_2+\rho_1\right)^{\frac{1}{1-\theta}}-\rho_1\underline{h}+\tau\right)^{\theta}}{2}\right)^{\frac{1}{\theta}} - \left(\frac{\left(\left(2\bar{h}\rho_2+\rho_1\right)^{\frac{\theta}{1-\theta}}+1\right)\bar{h}^{\theta}}{2}\right)^{\frac{1}{\theta}}$
Developer	$0 = \frac{\bar{h}^{\boldsymbol{\beta}+1}\alpha_1-\underline{h}^{\boldsymbol{\beta}+1}\alpha_1+\alpha_0\left(\bar{h}^{\boldsymbol{\beta}}-\underline{h}^{\boldsymbol{\beta}}\right)}{\bar{h}^{\boldsymbol{\beta}+1}\alpha_1^2+\bar{h}^{\boldsymbol{\beta}}\alpha_0\alpha_1+2\bar{h}\left(\bar{h}\alpha_1+\alpha_0\right)^2} - \frac{\left(-\rho_2(1+\delta)\underline{h}^3-\rho_1(1+\delta)\underline{h}^2-\rho_0(1+\delta)\underline{h}+\bar{h}\left(\bar{h}^2\rho_2+\bar{h}\rho_1+\rho_0\right)\right)\alpha_1+\alpha_0\left(-\rho_2(1+\delta)\underline{h}^2-\rho_1(1+\delta)\underline{h}+\bar{h}^2\rho_2+\bar{h}\rho_1-\delta\rho_0\right)}{3\left(\left(\bar{h}^2\rho_2+\frac{2}{3}\bar{h}\rho_1+\frac{1}{3}\rho_0\right)\alpha_1+\frac{2\left(\bar{h}\rho_2+\frac{\rho_1}{2}\right)\alpha_0}{3}\right)\left(\bar{h}\alpha_1+\alpha_0\right)}$

Main table