Housing Market Responses to Transaction Taxes: Evidence From Notches and Stimulus in the UK*

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Abstract

Using administrative data on the universe of property transactions in the UK from 2004-2012, we provide evidence on the distortionary effects of property transaction taxes ("stamp duty") on the housing market. Two sources of quasi-experimental variation allow us to obtain compelling graphical results: (i) notches created by discontinuous jumps in tax liability at threshold property prices, (ii) time variation created by permanent reforms and temporary stimulus in specific price brackets. Using notches, we find that the effect of transaction taxes on house prices is large and that dynamic adjustment to changes in transaction taxes is very fast. Using tax reforms and stimulus, we find that the effects of transaction taxes on the timing and volume of house purchases are also large. For example, a temporary elimination of transaction taxes stimulates housing market activity by 20% in the short run (due to timing and extensive responses) followed by a smaller slump in activity after the policy is withdrawn (as the timing effect is cancelled out). Due to the complementarities between moving house and consumer spending, these stimulus effects translate into GDP effects that are considerably larger than what has been found for other forms of fiscal stimulus.

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1 Introduction

Economists and policy makers have long debated what determines housing demand and prices. This debate has been particularly energetic in recent years due to the enormous turmoil in the housing market and its potential importance for the boom-bust cycle of the economy as a whole. Much academic work has considered the impact of different components of the cost of homeownership, including real interest rates and other credit market conditions (e.g. Himmelberg *et al.* 2005; Mian & Sufi 2009; Glaeser *et al.* 2010; Adelino *et al.* 2012) and tax subsidies such as the deductibility of mortgage interest, exemption of imputed rental income and preferential tax treatment of housing capital gains (e.g. Poterba 1984, 1992; Rosen 1985; Poterba & Sinai 2008). While the credit and tax literatures have lived somewhat separate lives, they relate to the same fundamental question regarding the responsiveness of the housing market to the cost of homeownership.

This paper addresses these questions using a piece of tax policy that has been largely overlooked by academics. This is the imposition in many countries—including the US and the UK —of substantial *transaction taxes* in connection with the buying and selling of property. These are one-off taxes imposed at the time of the transaction as opposed to the recurrent property taxes typically analyzed (e.g. Zodrow 2001). A transaction tax equal to t percent of the property value raises the interest cost per dollar of housing services from r to $r\,(1+t)$, thereby creating variation in the user cost of housing. We analyze the UK property transaction tax, known as the Stamp Duty Land Tax (SDLT), which is substantial in terms of both revenue and the distortions it introduces. The analysis is based on unique access to administrative stamp duty records covering the universe of property transactions in the UK from 2004–2012, about 10 million property transactions, with rich tax return information on each transaction.

Besides the quality of the data, two sources of quasi-experimental variation allow us to obtain compelling and striking evidence on housing market responses to transaction taxes. First, the UK stamp duty features large discontinuities in tax liability—*notches*—at cutoff property prices. For example, the tax rate jumps from 1% to 3% of the entire transaction price at a cutoff of £250,000 (about \$400,000), creating an increase in tax liability of £5,000 (about \$8,000) as the house price crosses this cutoff. Such notches create strong incentives for reducing house prices in a region above the cutoff to a point just below the cutoff, thereby creating a hole in the price distribution on the high-tax side and excess bunching in the price distribution on the low-tax side of the notch. This allows for non-parametric identification of house price responses to transaction taxes using a bunching approach (Saez 2010; Chetty *et al.* 2011; Kleven & Waseem 2013). Second, the UK stamp duty features subtantial time variation, including both permanent and temporary tax changes that affect specific price brackets but not others. For example, a *stamp duty holiday* lasting 16 months eliminated transaction taxes in a certain price range in order to provide stimulus to the housing market during the current recession, a policy that is qualitatively similar to the homebuyer tax credit introduced by the 2009 US Stimulus Bill. As we show, the UK reforms provide an ideal setting for a difference-in-differences approach to evaluating both extensive responses (whether or not to buy a house) and timing responses (when to buy a house) to permanent tax changes and temporary stimulus.

To facilitate interpretation of the empirical findings, we set out a conceptual framework that characterizes the effect of transaction taxes on housing demand at the intensive and extensive margins and on equilibrium house prices. Transaction taxes affect the market value of transacted houses ("house prices") through changes in both the demand for quality-adjusted units of housing and the price per unit. In particular, bunching at transaction tax notches may be generated by intensive demand responses and price bargaining, and in the benchmark case of a fully competitive housing market it would be driven solely by demand. However, bunching does not arise from standard market-level price incidence, and such effects are therefore not part of our estimates of house price responses to taxes. This is analogous to the literature on taxable income responses (Saez *et al.* 2012), which combines real labor supply and wage bargaining effects (but does not include standard wage incidence).

Our empirical findings can be divided into three main categories. First, there is large and sharp bunching just below notch points combined with large holes above notch points in the distribution of house prices. Our bunching estimates imply that house prices respond by a factor of 2-5 times the size of the tax increase at the notch, with larger effects at the bottom than at the top of the price distribution. Since notches create extremely large implicit marginal tax rates in the vicinity of the cutoff, the large bunching responses are consistent with more modest elasticities of house prices with respect to marginal tax rate, around 0.1-0.3 across most notches.

Second, we consider the dynamics of house price responses using both anticipated and unanticipated changes in the location of notches. The dynamic adjustment of bunching and holes to changes in notches is very fast, with a new steady state emerging in about 3-4 months for unanticipated changes and almost immediately for anticipated changes. Related, we find strong evidence of anticipatory behavior by exploiting the fact that pre-announced tax changes create *time notches* at cutoff dates, in addition to the *price notches* at cutoff house prices that exist at any point in time. Overall, the remarkable sharpness of our dynamic findings suggests that agents in the housing market are less affected by optimization frictions (inattention, inertia, etc.) than for example agents in the labor market (Chetty *et al.* 2011; Kleven & Waseem 2013).

Third, we estimate timing and extensive margin responses using both temporary and permanent tax reforms.[1] Temporary housing stimulus successfully boosts activity in the short run as transaction volumes in the treatment group clearly diverge from transaction volumes in a control group during the 16-month stamp duty holiday. A 1%-point cut in transaction taxes increases market activity by about 20% during the holiday. This effect combines a *timing effect* (intertemporal substitution by those who would have purchased a house anyway) and an *extensive margin effect* (house purchases

[1]These are extensive responses for house *purchases* as opposed to house *ownership*. Hence, our estimates of extensive responses do not just capture movements between renting and owning, but also that existing homeowners make additional house purchases (and therefore move more) over their lifetime.

that would not have taken place absent the tax holiday). We can separate the two effects by comparing treatments and controls following the removal of the stimulus policy. Consistent with a timing effect, activity levels in the treatment group drop by about 8% compared to the control group in the first year after the holiday, with no further reversal in the second year after the holiday. The total reversal effect due to re-timing is only between 30-50% of the total holiday boost, implying that the stimulus had a sizeable permanent effect. Our reversal findings differ from Mian & Sufi (2012), who find complete reversal within one year of a US stimulus program offering cash subsidies for automobile purchases.

Even though higher transaction levels in the housing market (for a given aggregate housing stock) do not add *mechanically* to real economic activity (GDP), house purchases have important real effects. Besides the implications of homeowner mobility for housing and labor markets, moving house is associated with substantial household spending on repairs, renovations, durable goods (domestic appliances, consumer electronics, furnishing, etc.), and commissions to agents and lawyers. Using UK consumption survey data, we estimate conservatively that a house transaction triggers extra spending of about 5% of the house price. Combined with our estimated increase in transaction volume (20%) and the size of the tax cut (1% of the house price), this implies that the amount of extra economic activity per dollar of tax cut is about 1. This captures only the immediate stimulus effect of larger spending; it does not include potential multiplier effects or indirect effects of mobility. Compared to a large body of evidence on consumer responses to other forms of fiscal stimulus such as tax rebates (e.g. Shapiro & Slemrod 2003a,b; Johnson *et al.* 2006; Agarwal *et al.* 2007; Kreiner *et al.* 2012), our findings suggest that the spending impact of the UK housing stimulus program have been considerably larger. The large effect is due to the strong responsiveness of house purchases to transaction taxes along with the complementarities between moving house and consumer spending.

Transaction taxes are understudied in the enormous empirical literature on taxation and our paper takes a step towards closing this gap. A small body of prior work has studied the effects of property transaction taxes on house prices and homeowner mobility in different countries (Benjamin *et al.* 1993; van Ommeren & van Leuvensteijn 2005; Besley *et al.* 2011; Dachis *et al.* 2012).[2] Moreover, related to our analysis of bunching and holes at price notches, two contemporaneous papers by Slemrod *et al.* (2012) and Kopczuk & Munroe (2013) find similar house price distortions using US tax notches. In contrast to the rest of the literature, we are able to simultaneously exploit a large dataset of administrative tax records along with multiple sources of quasi-experimental variation from notches, tax reforms and stimulus. This allows for compelling non-parametric identification of a broader set of responses (prices, timing, extensive margin) viewed both statically and dynamically, providing a quite complete picture of the (large) distortions introduced by transaction taxes.

The paper proceeds as follows. Section 2 presents our conceptual framework, section 3 describes the context and data, section 4 estimates house price responses using notches, section 5 estimates

[2] A much larger empirical literature has examined the impact of capital gains taxes on asset prices and asset transactions (e.g. Feldstein *et al.* 1980; Auerbach 1988; Burman & Randolph 1994) and some of this work has focused specifically on the taxation of housing capital gains (Cunningham & Engelhardt 2008; Shan 2011). Capital gains taxes and transaction taxes share the feature that tax liability is triggered by a transaction, with the key difference being that transaction taxes fall on the entire value of the asset and not just on the appreciation of the asset.

timing and extensive responses using stimulus and permanent reforms, and section 6 concludes.

2 Conceptual Framework

2.1 A Competitive Model of the Housing Market

To guide the empirical analysis, this section first develops a simple static model of a competitive housing market and then considers a dynamic extension of that model. The framework is deliberately unrealistic in some dimensions as our goal is to build the most parsinomious model possible that is still general enough to demonstrate the key empirical effects. The next section generalizes the analysis to a housing market with matching frictions and price bargaining.

Static Analysis: Agents choose whether or not to become homeowners (extensive margin) and how much housing to buy conditional on owning (intensive margin). Letting c denote units of a numeraire consumption good and h denote units of quality-adjusted housing stock, we consider the following parametrization of preferences

$$u\left(c,h\right)=c+\frac{A}{1+1/\alpha}\left(\frac{h}{A}\right)^{1+1/\alpha}-q\cdot I\left\{h>0\right\}, \tag{1}$$

where A,α are parameters characterizing housing preferences and q is a fixed cost of entering the owner-occupied market including both transaction costs (search costs, broker fees, etc.) and the utility from renting instead of owning. We allow for heterogeneity in all of these parameters captured by a smooth density distribution $f\left(A,\alpha,q\right)$. The quasi-linear utility function conveniently eliminates income effects on housing demand as we will focus purely on the price effect.

As a baseline, consider a flat transaction tax rate t on the value of housing purchased. Denoting the price per unit of housing by p and income by y, the budget constraint is given by

$$c+\left(1+t\right)ph=y. \tag{2}$$

Conditional on owning ($h>0$), maximizing utility (1) with respect to the budget constraint (2) yields the following housing demand function

$$h^{*}=A\left(\left(1+t\right)p\right)^{\alpha}, \tag{3}$$

where α is the price elasticity of housing demand. Indirect utility conditional on $h>0$ and exclusive of the fixed cost q can be defined as $v\left(\left(1+t\right)p,y\right)\equiv u\left(c^{*},h^{*}\right)+q$, while indirect utility conditional on $h=0$ is given by $u\left(y,0\right)=y$. The agent then enters the owner-occupied housing market iff

$$q\leq v\left(\left(1+t\right)p,y\right)-y\equiv q^{*} \tag{4}$$

Total housing demand is then given by

$$D\left(\left(1+t\right)p\right)=\int_{A}\int_{\alpha}\int_{0}^{q^{*}}h^{*}f\left(A,\alpha,q\right)dqd\alpha dA. \tag{5}$$

We will be agnostic about the details of the supply side and denote housing supply by $S\left(p\right)$. The equilibrium condition $D\left(\left(1+t\right)p\right)=S\left(p\right)$ determines the equilibrium price p as a function of $1+t$.

Now consider the introduction of a discrete jump Δt in the average transaction tax rate—a notch—at a cutoff property value. Denoting property value by $h_v\equiv ph$, the notched tax schedule can be written as $T\left(h_v\right)=t\cdot h_v+\Delta t\cdot h_v\cdot I\left\{h_v>\overline{h}_v\right\}$ where $\overline{h}_v$ is the cutoff and $I\left\{\cdot\right\}$ is an indicator for being above the cutoff. Figure 1 illustrates the implications of this notch in a budget set diagram (Panel A) and density distribution diagrams (Panels B-D). The budget set diagram (depicted in (h_v,c)-space) illustrates intensive responses among individuals with heterogeneous housing preferences A, but a specific demand elasticity α. The notch creates bunching at the cutoff $\overline{h}_v$ by all individuals in a preference range $\left(\overline{A},\overline{A}+\Delta\overline{A}\right)$, who would have bought houses on the segment $\left(\overline{h}_v,\overline{h}_v+\Delta\overline{h}_v\right)$ in the absence of the notch. The marginal bunching individual at $\overline{A}+\Delta\overline{A}$ is indifferent between the notch point $\overline{h}_v$ and the best interior location $\overline{h}_v^I$. No individual is willing to locate between $\overline{h}_v$ and $\overline{h}_v^I$, and hence this range is completely empty. The density distribution of property values corresponding to the budget set diagram (all A, one specific α) is shown in Panel B. Since the behavioral response in Panels A-B depends on the size of the demand elasticity α (and converges to zero for $\alpha=0$), the density distribution in the full population (all A,α) can be illustrated as in Panel C where some individuals are willing to buy just above the notch point.[3]

As shown by Kleven & Waseem (2013), the relationship between bunching and the demand elasticity can be characterized by considering the marginal bunching individual who is indifferent between the notch point and her best interior location. This indifference condition along with the first-order condition for the no-notch location $\overline{h}_v+\Delta\overline{h}_v$ implies a relationship $\Delta\overline{h}_v/\overline{h}_v=k\left(\alpha,\Delta t/\left(1+t\right)\right)$ where $k\left(\cdot\right)$ is monotonically increasing in both arguments.[4] Conversely, given the width of the bunching segment $\Delta\overline{h}_v$ (the estimation of which will be described later) and the tax parameters $\overline{h}_v$ and $\Delta t/\left(1+t\right)$, this condition gives a unique demand elasticity α. However, since such an approach would rely heavily on the functional form for utility as well as the competitive market assumption,

[3]Notice that the above characterization is based on a given price p per unit of housing. The tax-induced change in aggregate housing demand (from bunching as well as interior responses further up) will affect the equilibrium price, which by itself will shift indifference curves in Panel A (as they are depicted in (h_v,c)-space) and hence shift the density distribution of property values. The qualitative characterization above holds for any arbitrary price and therefore also for the new equilibrium price. The key insight is that, in this competitive model, price incidence occurs at the *market level* and therefore does not contribute to bunching and holes locally around notches. The next section considers a bargaining model where price incidence occurs at the *match level* in which case price incidence does create bunching and holes.

[4]Under the specific parametrization in (1), the relationship $\Delta\overline{h}_v/\overline{h}_v=k\left(\alpha,\Delta t/\left(1+t\right)\right)$ is implicitly defined by the following condition

$$\frac{1}{1+\Delta\overline{h}_v/\overline{h}_v}-\frac{1}{1+1/\alpha}\left[\frac{1}{1+\Delta\overline{h}_v/\overline{h}_v}\right]^{1+1/\alpha}-\frac{1}{1+\alpha}\left[1+\frac{\Delta t}{1+t}\right]^{1+\alpha}=0. \tag{6}$$

the empirical analysis focuses instead on a reduced-form approach to estimating the elasticity of house values h_v with respect to $1+t$ using bunching at notches.

In addition to intensive responses, the notch creates extensive responses above the cutoff by individuals close to being indifferent between buying and not buying (with $q \approx q^*$). However, such extensive responses will be negligible *just* above the cutoff. This can be seen by considering an individual who prefers a location on the segment $\left(\overline{h}_v, \overline{h}_v + \Delta\overline{h}_v\right)$ without the notch and therefore prefers the cutoff $\overline{h}_v$ with the notch (conditional on buying). For such an individual, the change in the threshold fixed cost Δq^* induced by the notch is given by

$$\Delta q^* = u\left(\overline{c}, \overline{h}_v/p\right) - u\left(c^*, h^*\right), \tag{7}$$

where $\overline{c}, \overline{h}_v/p$ is the consumption bundle obtained at the notch. As the preferred point absent the notch h^* converges to the cutoff $\overline{h}_v/p$ from above (and hence c^* converges to $\overline{c}$), Δq^* converges to zero and extensive responses disappears. Intuitively, if in the absence of the notch, an individual would choose to buy a house slightly above $\overline{h}_v$, then in the presence of the notch, she will be better off by buying a house at $\overline{h}_v$ (which is almost as good) rather than not buying at all. This reasoning implies that extensive responses affect the density distribution as illustrated in Panel D of Figure 1. These effects can be summarised in the following proposition

Proposition 1 (**Notches**)**.** *A transaction tax featuring a notch at a property value $\bar{h}_v$ at which the proportional tax rate jumps from t to $t + \Delta t$ induces*

(i) *an* ***intensive margin response*** *as agents in a house price range $\left(\overline{h}_v, \overline{h}_v + \Delta\overline{h}_v\right)$ bunch at the threshold $\bar{h}_v$, where the width of the bunching segment $\Delta\overline{h}_v$ is monotonically increasing in the demand elasticity α as characterized by equation (6); and*

(ii) *an* ***extensive margin response*** *as agents in the house price range $\left(\overline{h}_v, \infty\right)$ who are sufficiently close to indifference between buying and not buying, $q \in (q^* + \Delta q^*, q^*)$, no longer buy. The extensive response converges to zero just above the cutoff as $\Delta q^* \to 0$ for $h_v \to \overline{h}_v^+$.*

Dynamic Analysis: To guide the empirical analysis of temporary stimulus policy, let us briefly consider a dynamic extension of the previous model. In general, temporary tax changes will create both timing responses and extensive margin responses in the housing market. To see this, consider a simple two-period extension of the model in which agents maximise lifetime utility $u_1(c_1, h_1) + \beta u_2(c_2, h_2)$ where the per-period utility functions are given by

$$u_s(c_s, h_s) = c_s + \frac{A_s}{1 + 1/\alpha_s}\left(\frac{h_s}{A_s}\right)^{1+1/\alpha_s} - q_s \cdot I\left\{h_s \neq h_{s-1}\right\} \tag{8}$$

Note that all the preference parameters $\{A_s, \alpha_s, q_s\}$ are allowed to vary between periods. In each period, agents choose whether to be active in the housing market or whether to remain in their current house (either a rented house or a house they purchased in a previous period). For simplicity we will assume that all agents start out renting so that $h_0 = 0$ for all agents, but this does not affect any of the results. If agents choose to be active in the housing market in period s they pay a fixed cost q_s, choose the amount of housing to purchase h_s, and if $h_{s-1} \neq 0$, they also simultaneously sell their existing house. Agents also receive income of y_s in each period and so face a budget constraint analogous to equation (2) in each period $s \in \{1, 2\}$ given by[5]

$$c_s + p_s \left[(1 + t_s) h_s - h_{s-1} \right] \cdot I \{ h_s \neq h_{s-1} \} = y_s \tag{9}$$

Solving the model backwards, consider an individual who enters period 2 with housing $h_1 \geq 0$. Just as in the static case, this individual will maximise $u_2(c_2, h_2)$ subject to her budget constraint (9) and, conditional on buying, demand housing $h_2^* = A_2 \left[(1 + t_2) p_2 \right]^{\alpha_2}$. This agent therefore buys a new house iff $u_2(c_2^*, h_2^*) > u_2(y_2, h_1)$ and we can write her indirect utility as $v_2((1 + t_2) p_2, y_2, h_1) = \max \{ u_2(c_2^*, h_2^*), u_2(y_2, h_1) \}$. Working backwards, individuals in period 1 anticipate the effect that their housing choices will have on their utility in period 2, so they maximise $u_1(c_1, h_1) + v_2((1 + t_2) p_2, y_2, h_1)$ subject to the period 1 budget constraint (9), again yielding a period-1 housing demand function h_1^* conditional upon buying. Individuals therefore buy in period 1 whenever $u_1(c_1^*, h_1^*) + \beta v_2((1 + t_2) p_2, y_2, h_1^*) > u_1(y_1, 0) + \beta v_2((1 + t_2) p_2, y_2, 0)$. In this model there will, in general, be four groups of agents: those who buy a house in period 1 and stay in it in period 2; those who buy in period 1 and then move in period 2; those who do not buy in period 1 but do so in period 2; and those who never buy.

If we now consider a reduction in the first-period tax t_1, this unambiguously makes buying a house in period 1 more attractive by lowering the net-of-tax price of housing. This has two conceptual effects on the level of activity in the housing market in period 1. First there will be a *timing effect* as agents who were close to indifferent between buying in period 2 and buying in period 1, i.e. those for whom $y_1 + \beta u_2(y_2 - p_2(1 + t_2) h_2^*, h_2^*) \approx u_1(c_1^*, h_1^*) + \beta u_2(y_2, h_1^*)$, buy a house in period 1 instead of waiting until period 2. Second, there will be an *extensive margin effect* by two types of agents. Those who were close to indifferent between never buying and buying in period 1, i.e. those for whom $y_1 + \beta u_2(y_2, 0) \approx u_1(c_1^*, h_1^*) + \beta v_2((1 + t_2) p_2, y_2, h_1^*)$, buy in period 1 instead of not buying at all. Furthermore, those who were close to indifferent between buying only in period 2 and buying in both periods, i.e. those for whom $y_1 + \beta u_2(y_2 - p_2(1 + t_2) h_2^*, h_2^*) \approx u_1(c_1^*, h_1^*) + \beta u_2(y_2 - p_2[(1 + t_2) h_2^* - h_1^*], h_2^*)$, are induced to buy twice over their lifetime instead of only once. To summarise,

Proposition 2 (**Temporary Stimulus**). *An unanticipated temporary stimulus policy reducing the transaction tax in period 1, but not in period 2, causes*

(i) *a* ***timing effect*** *as agents who were sufficiently close to indifference between buying in period 1 and buying in period 2 (preferring the latter) are induced to shift their house purchase forward; and*

(ii) *an* ***extensive margin effect*** *by two sets of agents. Those who were sufficiently close to*

[5] In this formulation, we can think of p_s as the price of 1 unit of housing services in every period from the current period onwards. In a model without liquidity constraints and in which utility is quasilinear this is, of course, immaterial. Moreover, even in a richer model the qualitative predictions that we explore in our empirical analysis will be unchanged.

indifference between buying in period 1 and never buying (preferring the latter) are induced to buy in period 1. Those who were sufficiently close to indifference between buying in both periods and buying only in period 2 (preferring the latter) are induced to buy twice over their lifetime intead of only once.

2.2 A Matching Frictions Model of the Housing Market

A key feature of the competitive housing market model is that excess bunching and holes around notch points reflect real demand responses (as opposed to price incidence) and therefore reveal the elasticity of real housing demand. This section shows that the same qualitative effects on the house price distribution can be generated by bargaining between buyers and sellers in a model with matching frictions.[6] In this model, bunching responses reflect the bargaining power of buyers versus sellers.

Consider a specific match where the buyer has valuation B_v and the seller has valuation S_v of the property. Considering a flat transaction tax t (remitted by the buyer), the buyer's surplus from trading at the before-tax house price h_v is equal to $B_v - (1+t)\,h_v$ and the seller's surplus is equal to $h_v - S_v$. The necessary and sufficient condition for a trade to take place is that there exists a price such that both traders obtain a positive surplus, i.e. we must have $S_v \leq \frac{B_v}{1+t}$.

The buyer and seller engage in Nash bargaining with bargaining power β for the buyer and $1-\beta$ for the seller. The agreed before-tax price h_v^* maximizes $W = [B_v - (1+t)\,h_v]^{\beta}\,[h_v - S_v]^{1-\beta}$, which yields

$$h_v^* = \beta S_v + (1-\beta)\,\frac{B_v}{1+t}. \tag{10}$$

Hence, conditional on trading, the transaction tax reduces the house price h_v^*, with the strength of the price effect being proportional to the bargaining power of the seller $1-\beta$. This means that we can characterize the effects of the transaction tax t in the following way. House transactions that were desirable to the buyer and seller in the absence of transaction taxes but sufficiently close to the indifference margin for both $(B_v/(1+t) < S_v \leq B_v)$ will no longer occur (extensive response). House transactions that continue to be desirable in the presence of transaction taxes $(S_v \leq B_v/(1+t))$ will occur at lower prices according to equation (10). Assuming a smooth distribution of matches S_v, B_v and bargaining power β, captured by a density distribution $f(S_v, B_v, \beta)$, there will be a smooth distribution of traded house prices under the flat transaction tax t.

Consider now the introdution of a notch Δt in the transaction tax at the cutoff house price $\overline{h}_v$. Under the notched tax schedule and Nash bargaining between the buyer and seller, the agreed house price h_v is picked to maximize

$$W = \left[B_v - \left(1 + t + \Delta t \cdot I\left\{h_v > \overline{h}_v\right\}\right) h_v\right]^{\beta} [h_v - S_v]^{1-\beta}. \tag{11}$$

In general, solving this bargaining problem requires us to solve for the best price point within each

[6] Our matching frictions model for the housing market is conceptually similar to the labor market model used by Kleven *et al.* (2013) to study income taxes and migration.

tax bracket (below and above $\overline{h}_v$) and then pick the candidate solution that yields the largest welfare W. Trades that would occur below $\overline{h}_v$ under the baseline flat tax are clearly unaffected by the notch and continue to feature house prices given by (10). On the other hand, trades that would occur above $\overline{h}_v$ under the baseline flat tax are affected by the notch. To see how these trades are affected, note first that any trade occurring stricly above the cutoff must satisfy the interior pricing condition (10) with the $1+t$ replaced by $1+t+\Delta t$. This allows us to distinguish between three cases.

First, some transactions just above $\overline{h}_v$ under the baseline tax rate t would have an interior solution below $\overline{h}_v$ under the larger tax rate $t+\Delta t$ (based on eq. (10) at tax rate $1+t+\Delta t$). This is inconsistent with an interior solution in either bracket, and so these transactions bunch at the cutoff. Second, some transactions that were taking place in a region $\left(\bar{h}_v, \bar{h}_v + \Delta\bar{h}_v\right)$ in the absence of the notch and that would be just above $\overline{h}_v$ under an interior solution at the new tax rate $t+\Delta t$ (again based on eq. (10) at tax rate $1+t+\Delta t$) also bunch at the cutoff. For such transactions, a small move to the cutoff provides a discrete gain to the buyer and only a marginal loss to the seller, yielding a larger value of W than at the interior location. Of course, for such a move to be possible, it must be the case that the seller still receives positive surplus, so only those transactions for which $S_v \leq \bar{h}_v$ will bunch. Given a smooth distribution of matches (S_v, B_v), there will be marginal bunching transactions such that welfare at the cutoff $\overline{h}_v$ is precisely equal to welfare at the best interior location above the notch $\bar{h}_v^I$. In the interval $\left(\overline{h}_v, \bar{h}_v^I\right)$ all transactions with $S_v \leq \bar{h}_v$ move to the threshold and so we get a hole in the price distribution there. The width of this hole depends on bargaining power and converges to zero as the bargaining power of the buyer β converges to zero.[7] Third and finally, transactions above $\bar{h}_v^I$ under an interior solution at the new tax rate $t+\Delta t$ are associated with a larger W at the new interior solution than at the cutoff. For those transactions, we get a downward price shift within the upper bracket.

This characterization applies only to matches for which a trade is still beneficial. The notch will also create extensive responses above the cutoff as house transactions that were desirable to the buyer and seller under the flat tax but close enough to the indifference margin for both $(B_v/(1+t+\Delta t) < S_v \leq B_v/(1+t))$ and which cannot take place with positive surplus at the notch (as $\bar{h}_v < S_v$) will no longer occur. Nevertheless, as in the competitive model, extensive responses are negligible *just* above the cutoff. Trades that would occur at a price $h_v \in \left(\bar{h}_v, \bar{h}_v + \Delta\bar{h}_v\right)$ in the absence of the notch (but have a negative surplus under the higher tax, i.e. $B_v/(1+t+\Delta t) < S_v \leq B_v/(1+t)$) must have a positive surplus under the lower tax such that $S_v \leq h_v \leq B_v/(1+t)$. In the presence of the notch, for those trades to take place at the cutoff price $\bar{h}_v$ it must be the case that $S_v \leq \bar{h}_v \leq B_v/(1+t)$. Together these conditions imply that those trades cannot achieve positive surplus by bunching at the notch whenever $S_v \in NT = \left(\bar{h}_v, h_v\right)$. As the price absent the notch h_v converges to $\bar{h}_v$ from above, we see that the no-trade set NT becomes empty and so there

[7] These marginal transactions satisfy

$$\left(B_v - (1+t)\,\bar{h}_v\right)^{\beta} \left(\bar{h}_v - S_v\right)^{1-\beta} = \left(B_v - (1+t+\Delta t)\,\bar{h}_v^I\right)^{\beta} \left(\bar{h}_v^I - S_v\right)^{1-\beta} \tag{12}$$

where $\bar{h}_v^I = \beta S_v + (1-\beta)\frac{B_v}{1+t+\Delta t}$ and $\bar{h}_v + \Delta\bar{h}_v = \beta S_v + (1-\beta)\frac{B_v}{1+t}$. From this we can also immediately see that the width of the hole converges to 0 as the bargaining power parameter β converges to 0.

is no extensive margin response just above the threshold. Finally, note that the presence of the notch could shift the distribution of buyer and seller matches S_v, B_v above the notch, for example, by inducing buyers and sellers with valuations that put them near the notch to continue searching in order to find another match. We supress these effects for simplicity, but again, they will be negligible *just* above the notch.

The characterization above is analogous to the characterization for the competitive model, with the bargaining power parameter β in the bargaining model playing the role of the demand elasticity α in the competitive model. A graphical illustration similar to Figure 1 is also possible. Figure A.1 shows the direct analog of panel A of Figure 1 for the case of the bargaining model, and shares all of its qualitative features. The density diagrams in panels C-D of Figure 1 can also be reinterpreted in terms of the bargaining model, with panel C depicting the intensive margin effects on the house price distribution for the full distribution of βs and panel D incorporating the extensive margin effects. We can summarise the bargaining model's predictions as follows

Proposition 3 (**Notches with Matching Frictions**). *A transaction tax featuring a notch at a property value $\bar{h}_v$ at which the proportional tax rate jumps from t to $t + \Delta t$ induces*

(i) *an* ***intensive margin response*** *as matches in the house price range $\left(\bar{h}_v, \bar{h}_v + \Delta\bar{h}_v\right)$ for which $S_v \leq \bar{h}_v$ bunch at the threshold $\bar{h}_v$, where the width of the bunching segment $\Delta\bar{h}_v$ is monotonically increasing in the bargaining power parameter β as characterized by equation (12); and*

(ii) *an* ***extensive margin responses*** *as matches in the house price range $h_v \in \left(\bar{h}_v, \infty\right)$ for which $B_v/\left(1 + t + \Delta t\right) < S_v \leq B_v/\left(1 + t\right)$ and $S_v \in NT = \left(\bar{h}_v, h_v\right)$ choose not to trade. The extensive response converges to zero just above the cutoff as the set NT converges to the empty set as $h_v \to \bar{h}_v^+$.*

3 Context and Data

3.1 The UK Property Transaction Tax: Notches and Reforms

The UK property transaction tax—Stamp Duty Land Tax (SDLT)—is imposed on the transaction value of land and any construction on the land, known as the "chargeable consideration".[8] This is defined in the broadest possible terms to include anything of economic value given in exchange for land or property, including money, goods, works or services, and transfers of debts. The statutory incidence of the SDLT falls on the buyer, who is required to file a stamp duty return and remit tax liability to HMRC within a few weeks of the completed transaction. The SDLT is a significant source of government revenue in the UK, much more so than other wealth transfer taxes such as inheritance taxation and capital gains taxation. The SDLT has raised revenue of around 0.6% of GDP over recent years,[9] and the political debate in the UK suggests that future rates (on highly priced properties) are more likely to go up than down.

[8] The chargeable consideration includes the buildings and structures on the land as well as fixtures and fittings (such as in bathrooms and kitchens), but excludes freestanding furniture, carpets or curtains. If such extras are included in the sale, the buyer and seller are to agree on the market value of these extras and subtract it from the chargeable consideration. See http://www.hmrc.gov.uk/sdlt/calculate/value.htm for details.

[9] See http://www.hmrc.gov.uk/stats/tax_receipts/tax-receipts-and-taxpayers.pdf.

A central aspect of the stamp duty is that it features discrete jumps in tax liability—notches—at threshold property prices. Tax liability is calculated as a proportional tax rate times the transacted property price, with different tax rates in different price brackets. Hence, as the purchase price crosses a bracket threshold, a higher tax rate applies to the entire amount and not just the portion that falls above the cutoff as in standard graduated schedules. Figure 2 illustrates the stamp duty schedule for residential property in tax year 2012-13.[10] The schedule features five notches as the proportional tax rate jumps from zero to 1% at a price of £125K, from 1% to 3% at a price of £250K, from 3% to 4% at a price of £500K, from 4% to 5% at a price of £1,000K, and finally from 5% to 7% at a price of £2,000K.[11] The schedule is different for residential property in certain disadvantaged areas (where the first bracket threshold is at a higher price) as well as for non-residential property. It is worth noting that the buyer cannot mortgage the SDLT liability, it must be financed from savings, and so we should expect the SDLT to have large effects on liquidity constrained buyers. It should also be noted that stamp duty schedules are not indexed for inflation, which creates "bracket creep" as property price inflation pushes houses into higher stamp duty brackets.

Another important aspect of the stamp duty is that it has been subject to a great deal of policy experimentation over the years. As shown in Table 1, the main policy experiments during our data period have been (*i*) changes in the location of the lower notch and (*ii*) the introduction of new notches at £1,000K in April 2011 and at £2,000K in March 2012. It is worth describing the specific features of some of those policy changes as they will be important for the empirical analysis.

For the lower notch, the most salient change was the so-called *stamp duty holiday* between 3 September 2008 and 31 December 2009, which moved the first notch point from £125K to £175K and thereby eliminated stamp duty in a £50K range. The motivation of the program was to provide housing stimulus during the current recession.[12] The following features of the stamp duty holiday are important for our analysis. First, the beginning of the holiday was *unanticipated* as it was announced suddenly by the then Chancellor Alistair Darling on the day before its introduction. Although there was some media speculation about the possibility of a stamp duty holiday in the month leading up to the announcement, the details and start date of such a holiday were unknown. Second, the end of this holiday was *anticipated*. The initial announcement was that the holiday would last for one year (until September 2009), but in April 2009 this was extended until the end of 2009 and the government committed to no further extensions (and indeed did not grant any extensions). The sudden announcement of the stamp duty holiday and the preannounced committment to its end date allow us to compare the effects of expected and unexpected changes in tax policy. In particular, the pre-announced end date creates a *time notch* (a discrete jump in tax liability at a cutoff date) allowing us to analyze short-term timing effects. Finally, as the stamp duty holiday applied only to properties in a certain price range, we are able to study the stimulus effects of the

[10] The UK tax year for personal taxes runs from April 6 in one year to April 5 the next year.

[11] At the £2,000K notch, the stamp duty rate jumps to 15% if the residential dwelling is purchased by certain "non-natural persons" such as corporations and collective investment schemes.

[12] Another stimulus program was implemented specifically for first-time buyers between 25 March 2010 and 24 March 2012. This program temporarily abolished the notch at £125K, thereby eliminating stamp duty in the range between £125K and £250K for first-time buyers.

policy and subsequent reversal (medium-term timing) using a difference-in-differences approach.

For the top notches, the introduction of a higher stamp duty rate above £1,000K was pre-announced a full year in advance, while the higher stamp duty rate above £2,000K was confirmed just one day before it took effect. Hence, the introduction of the £1,000K price notch (but not the £2,000K price notch) also creates a time notch that allows us to study anticipatory behavior.

The UK stamp duty appears to be characterized by relatively high compliance. According to HMRC estimates, the so-called *tax gap*—the difference between taxes owed and taxes paid on a timely basis—is between 4-5% of true stamp duty tax liability. This is lower than the tax gap estimates for most other taxes in the UK. It is perhaps not surprising that tax evasion is a minor issue for this tax when considering the following points. First, almost all property transactions in the UK are facilitated by licensed real estate agencies, implying that stamp duty tax evasion requires collusion between a buyer, a seller and a real estate agency (typically with multiple employees). Such evasion collusion involving many agents is unlikely to be sustainable (Kleven *et al.* 2009). Second, the scope for tax evasion is further reduced by the existence of a considerable lag between agreeing on a house price and completing the contract.[13] If the house price reported to tax authorities is lower than the true house price, the buyer must make a side payment to the seller. If the buyer makes the side payment at the time of agreeing on the house price, the seller would be able renege before completing the contract and it would be difficult for the buyer to recoup the payment. If instead the buyer promises to make the payment at the time of completing the contract, the seller would take his property off the market with no credible commitment from the buyer that he would not renege later when the bargaining position of the seller may be weaker. Hence, such side payments would be associated with substantial risk for either the buyer or the seller or both. Finally, as described above, the tax base is defined in an very comprehensive manner meaning that the scope for shifting or re-classification of specific features of the property to avoid the tax is limited. The one exception is the exclusion in the tax base of freestanding "extras" such as furniture and curtains. If such extras are included in the sale, the buyer and seller are to agree on the market value of these extras and subtract it from the chargeable consideration, which creates an opportunity to evade stamp duty by overvaluing such items (while undervaluing the rest of the property by the same amount). However, reporting large amounts of tax exempt extras is an audit trigger, limiting the degree to which such behavior is possible. For all of these reasons, we believe that house prices reported on stamp duty tax returns reflect true house prices in most (but not all) cases.

3.2 Data and Raw Time Series Evidence

The empirical analysis is based on administrative data covering the universe of stamp duty (SDLT) returns in the UK from November 2004 to October 2012. Since most property transactions require the filing of an SDLT return (the main filing exemption being for property transactions under £40,000), our data is close to the universe of property transactions in the UK. The full dataset contains about 10 million transactions. The dataset contains rich tax return information for each

[13] This lag is about 2 months on average in the UK housing market (Besley *et al.*, 2011).

transaction, but currently very little information outside the tax return.

The housing market has seen substantial turmoil during the period we consider. Figure 3 shows the monthly number of house transactions (Panel A) and the monthly average property price (Panel B) in all of the UK and in London alone. The figure shows nominal prices (real prices give the same qualitative picture) and normalizes both the price and the number of transactions to one at the start of the period. We make the following observations. First, housing market activity collapses between late 2007 and early 2009 as the the number of transactions falls by around two-thirds. There has been some recent recovery, but activity is still very far from pre-recession levels. Second, property prices also fall between late 2007 and early 2009, but the price drop is less dramatic and the subsequent recovery much stronger. Third, property prices (though not activity) in London have evolved differently than in the rest of the UK during the recession. While UK-wide property prices have recovered only partially in the past couple of years, London property prices are almost back on their pre-recession trend. Fourth, the recovery in house prices and activity throughout 2009 coincides with the stamp duty holiday, which has been used as an argument that the policy had the desired effect. We will take a quasi-experimental approach to evaluate how much of the recovery (if any) can indeed be explained by the stamp duty holiday. Finally, average house prices in London feature a sharp spike in early 2011 and a subsequent dip, which constitutes our first piece of evidence of a behavioral response to stamp duty incentives. This spike reflects excess trading of houses above £1,000K just before the pre-announced introduction of the £1,000K stamp duty notch on 6 April 2011 and the dip reflects missing trading of such houses just after the introduction of the notch—a short-term timing response to an anticipated tax change.

4 Estimating House Price Responses Using Notches

4.1 Bunching Methodology

As elucidated in the theoretical frameworks of section 2, we expect a transaction tax notch at the cutoff property price $\bar{h}_v$ to induce excess bunching at the cutoff by properties that would have been sold at prices between $\bar{h}_v$ and $\bar{h}_v + \Delta\bar{h}_v$ absent the notch. In the competitive model of section 2.1 this effect was driven by real responses governed by the demand elasticity α, while in the bargaining model of section 2.2 the effect was driven by price incidence governed by the bargaining power β of buyers relative to sellers. In both cases, these effects generated an excess mass of

$$B\left(\bar{h}_v\right) = \int_{\bar{h}_v}^{\bar{h}_v+\Delta\bar{h}_v} g_0\left(h_v\right) dh_v \approx g_0\left(\bar{h}_v\right) \Delta\bar{h}_v, \tag{13}$$

where $B\left(\bar{h}_v\right)$ is excess mass at the cutoff and $g_0\left(h_v\right)$ is the counterfactual density of house values (i.e. the density that would prevail absent the notch). The approximation is accurate to the extent that the counterfactual is approximately uniform around the notch. Based on equation (13), it is possible to recover the house price response $\Delta\bar{h}_v$ based on estimates of the counterfactual distribution $g_0\left(h_v\right)$ and bunching $B\left(\bar{h}_v\right)$.

The relationship (13) implicitly assumes that there is just one bunching segment $\left(\bar{h}_v, \bar{h}_v + \Delta\bar{h}_v\right)$, which amounts to an assumption that the underlying driver of price response (demand elasticity α or bargaining power β) is homogeneous in the population. Our conceptual framework allows for heterogeneity and we can also account for it in the empirical implementation. Denoting the underlying source of heterogeneity by $x = (\alpha, \beta)$, there will be a price response $\Delta\bar{h}_v(x)$ and a counterfactual density $\tilde{g}_0(h_v, x)$ associated with each type x. In this case, eq. (13) can be generalized to

$$B\left(\bar{h}_v\right) = \int_x \int_{\bar{h}_v}^{\bar{h}_v + \Delta\bar{h}_v(x)} \tilde{g}_0(h_v, x)\, dh_v dx \approx g_0\left(\bar{h}_v\right) E\left[\Delta\bar{h}_v\right], \tag{14}$$

where $E\left[\Delta\bar{h}_v\right]$ is the average price response across all x. As before, the approximation requires that the counterfactual density is locally uniform in house prices h_v (but not type x) around the notch point. Equation (14) shows that estimates of the counterfactual distribution and bunching allows us to recover the average house price response in the population.

Based on the estimated house price response to the notch, it is possible to infer the elasticity of house prices with respect to the marginal tax rate using the reduced-form approximation approach developed by Kleven & Waseem (2013). The reduced-form approach is appealing, because it allows us not to commit to a particular model or parametrization. The idea of the approach is to relate the house price response $\Delta\bar{h}_v$ to the change in the implicit marginal tax rate between $\bar{h}_v$ and $\bar{h}_v + \Delta\bar{h}_v$ created by the notch. Defining this implicit marginal tax rate as $t^* = \left\{T\left(\bar{h}_v + \Delta\bar{h}_v\right) - T\left(\bar{h}_v\right)\right\}/\Delta\bar{h}_v$, the house price elasticity with respect to $(1+t^*)$ is given by

$$\varepsilon_v \equiv \frac{\Delta\bar{h}_v/\bar{h}_v}{\Delta t^*/(1+t^*)} \approx \frac{\left(\Delta\bar{h}_v/\bar{h}_v\right)^2}{\Delta t/(1+t)}, \tag{15}$$

where the notch-induced change in the implicit marginal tax rate is approximated as $\Delta t^* \approx \left\{\Delta t \cdot \bar{h}_v\right\}/\Delta\bar{h}_v$. The advantage of estimating a house price elasticity with respect to the *marginal* tax rate (using notches that create jumps in the *average* tax rate) is that it allows for an evaluation of house price responses in the interior of tax brackets (where individuals are responding to marginal tax rate changes) and also for an evaluation of alternative non-notched tax structures.

4.2 House Price Responses: Static Analysis

This section presents static results using price notches during periods when they are stable. We consider residential property transactions that incur a stamp duty land tax liability.[14] Figure 4 considers the two notches located at cutoff prices of £250,000 (Panel A) and £500,000 (Panel B), both of which have remained in place throughout the period of our data. Each panel shows the empirical distribution of house values (blue dots) as a histogram in £5,000 bins and an estimated counterfactual distribution (red line). Following Chetty *et al.* (2011) and Kleven & Waseem (2013), the counterfactual distribution is estimated by fitting a flexible polynomial to the empirical distribution, excluding data in a range around the notch, and allowing for round-number fixed effects to

[14] Results for non-residential property are qualitatively similar, but noisier as we have far fewer observations.

capture rounding in the price data.[15] The excluded range is demarcated by vertical dashed lines; the lower bound is set at the point where excess bunching starts and the upper bound is set at the point where the hole ends (where the empirical distribution above the cutoff changes slope from positive to negative).

As discussed in detail by Kleven & Waseem (2013), due to the presence of potential extensive responses above the excluded range, this estimation procedure intends to provide a "partial counterfactual" stripped of intensive responses, but not extensive responses. This partial counterfactual corresponds to the border of the light-gray area in Panel D of Figure 1, which is smooth around the cutoff. To simplify, our estimation of the counterfactual distribution ignores the marginal shift in the distribution above the hole due to intensive responses in the interior of the upper bracket. It is feasible to account for this shift in the distribution when estimating the counterfactual,[16] but given the size of the incentive (a marginal tax rate change of 1-2% above the notch) and the house price elasticities that we find, this shift will be extremely small and have no substantive effect on any of our conclusions.

In Figure 4, each panel shows estimates of excess bunching below the notch scaled by the counterfactual frequency at the notch (b), the size of the hole (missing mass) above the notch scaled by the counterfactual frequency at the notch (m), the difference between these two ($m - b$), the average house response to the notch (Δh_v), the tax liability change at the notch (ΔTax), and the implied house price elasticity with respect to the marginal tax rate (ε_v defined in equation (15)).

Our main findings are the following. First, both notches create large and sharp bunching below the cutoff. Excess bunching is 1.85 and 1.64 times the height of the counterfactual distribution at £250,000 and £500,000, respectively, and is strongly significant in each case. Second, both notches are associated with a large hole in the distribution above the cutoff. The size of the hole is

[15] Grouping transactions into price bins of £100, the regression used to estimate the counterfactual distribution around a notch at price $\bar{h}_v$ is given by

$$c_i = \sum_{j=0}^{q} \beta_j (z_i)^j + \sum_{r \in \mathcal{R}} \eta_r I\left\{\frac{\bar{h}_v + z_i}{r} \in \mathbb{N}\right\} + \sum_{k=\bar{h}_v^-}^{\bar{h}_v^+} \gamma_k I\{i = k\} + \mu_i, \tag{16}$$

where c_i is the number of transactions in price bin i, z_i is the distance between price bin i and the cutoff $\bar{h}_v$, and q is the order of the polynomial ($q = 5$ in Figure 4). The second term in (16) includes fixed effects for prices that are multiples of the round numbers in the set $\mathcal{R}$, where $\mathcal{R} = \{500, 1000, 5000, 10000, 25000\}$, $\mathbb{N}$ is the set of natural numbers, and $I\{\cdot\}$ is an indicator function. Finally, the third term in (16) excludes a region $\left(h_v^-, h_v^+\right)$ around the notch that is distorted by bunching responses to the notch, and μ_i is a residual reflecting misspecification of the density equation. Our estimate of the counterfactual distribution is defined as the predicted bin counts $\hat{c}_i$ from (16) omitting the contribution of the dummies in the excluded range, and excess bunching is estimated as the difference between the observed and counterfactual bin counts in the part of the excluded range that falls below the notch $\hat{B} = \sum_{i=\bar{h}_v^-}^{\bar{h}_v} (c_i - \hat{c}_i)$. We may also define an estimate of missing mass (the hole) above the notch as $\hat{M} = \sum_{i>\bar{h}_v}^{\bar{h}_v^+} (\hat{c}_i - c_i)$, but this statistic is not used in the estimation of house price responses and house price elasticities (see section 4.1). Standard errors on all estimates are calculated based on a bootstrap procedure as in Chetty *et al.* (2011). As a robustness check we have tried values between 4 and 7 for the order of the polynomial and our results are not significantly altered.

[16] This can be done by using an initial estimate of the house price elasticity (based on ignoring the shift in the upper distribution) to obtain an initial estimate of the distribution shift, re-estimate the counterfactual and the house price elasticity to respect the initial estimate of the distribution shift, and continue the procedure until the estimation converges.

larger than the size of excess bunching, although the difference between the two is not statistically significant from zero. Third, the hole in the distribution spans a £25,000 range above each cutoff, implying that the most responsive agents reduce their transacted house value by five times as much as the jump in tax liability of £5,000.[17] Fourth, the average house price response is £10,000 at both the £250,000 notch and the £500,000 notch, a response that is twice as large as the tax jump. Finally, the figure also shows estimates of the house price elasticity with respect to the marginal tax rate by relating the house price response (10K/250K = 4% in Panel A) to the notch-induced change in the implicit marginal tax rate over the response segment ($\{5K/10K\}/(1+t) \approx 50\%$ in Panel A). Despite the large house price responses, elasticities are relatively modest (below 0.1) due to the enormous marginal tax rate variation driving those responses. The presence of modest house price elasticities with respect to the marginal tax rate implies that house price responses outside the regions around notches (where individuals are responding to standard marginal tax incentives) are quite modest.

We now turn to the lower notch, the location of which has changed several times during the period under consideration. The cutoff was located at £60,000 until 16 March 2005, at £120,000 between 17 March 2005 and 22 March 2006, at £125,000 between 23 March 2006 and 2 September 2008, at £175,000 between 3 September 2008 and 31 December 2009, and again at £125,000 from 1 January 2010 onwards. This section takes a static approach by considering bunching responses within each of these five periods separately, while the next section investigates dynamic adjustment paths around the reform episodes. Figure 5 shows results for the five periods in separate panels, each of which is constructed as in the Figure 4. The findings for the lower notch are qualitatively consistent with those for the other notches, with a clear and statistically significant bunching response to the tax notch in each period. The size of the bunch and the hole is smaller at the lower notch than at the upper notches, but so is the size of the notch. The effect of the notch on the average transacted house value is between £3,500 and £5,000, or about 4–5 times the size of the tax liability jump. Hence, responses are proportionally larger at the bottom, and by implication so are the house price elasticities (around 0.2-0.3 in most periods).

In 2011 and 2012, the government introduced two new notches affecting very high value properties, one at £1 million on 6 April 2011 and another one at £2 million on 22 March 2012. The stamp duty notch at £2 million is commonly referred to as the "mansion tax". Even though these are very recent notches, they have already created a clear house price distortion as shown in Appendix Figure A.2. This figure is constructed in the same way as the previous ones, except that the counterfactual distribution is obtained differently. We take advantage of the tax reform (notch introduction) by comparing the empirical house price distribution after the introduction of the notch to the empirical

[17]This finding is interesting when considering mortgage terms in the UK. Mortgage rates depend on the downpayment as a share of the house price according to a notched schedule, with the credit terms improving drastically if the borrower is able to put down a deposit of at least 20%. Hence, if a buyer is targeting the 20% mortgage notch *and* is liquidity constrained, the house price is fixed at five times savings net of stamp duty payments (recall that stamp duty cannot be mortgaged). This implies that the house price responds precisely by a factor of five to the stamp duty. In future work, we plan to investigate the role of liquidity constraints for the joint responsiveness to taxes and mortgage rates using administrative mortgage data.

distribution in the year leading up to the introduction of the notch. The results are qualitatively very similar to the previous results, with an average house price response of £30,000 at the £1 million notch (3 times the tax liability jump of £10,000) and £100,000 at the £2 million notch (2.5 times the tax liability jump of £40,000).

Finally, when interpreting our results, note that reported house prices in our data can be described by $h_v \equiv p \cdot h - e$, where p is the price per unit of quality-adjusted housing, h is the amount of quality-adjusted housing, and e is stamp duty evasion. This means that, in general, our estimates of house price responses combine price changes Δp (incidence), real demand changes Δh (buying a lower-quality house), and evasion responses Δe. As clarifed in the theory section, the price incidence effect reflects potential match-specific price bargaining rather than standard market-level incidence driven by aggregate demand and supply (which does not by itself create bunching). Our estimates of house price responses are conceptually similar to the estimation of taxable income responses (e.g. Saez *et al.* 2012), which combines wage bargaining effects, real labor supply, and evasion.

4.3 House Price Responses: Dynamic Analysis

This section investigates the dynamics of behavioral adjustment to the changes in the position of the lower notch that were mentioned above. When considering dynamic adjustments, it is important to keep in mind that there is always a lag between agreeing on a purchase price and completing the housing contract. In the UK housing market, this lag is under 90 days for most transactions and about 60 days on average (Besley *et al.* 2011). Since the official transaction date in our data refers to contract completion, the time it takes for the market to settle into a new equilibrium is bounded from below by about 3 months.

Figure 6 considers the movement of the lower notch from £120,000 to £125,000 on 23 March 2006. Each panel shows the empirical and counterfactual distributions in a given month between February 2006 and September 2006. The two vertical lines demarcate the £120,000 and £125,000 cutoffs and are either solid green (for the cutoff that is active in month in question) or dashed black (for the cutoff that is inactive). April 2006 is the first full month where the new cutoff is in place. The figure shows very clearly how the bunch moves over time in response to the changed location of the notch. Most of the adjustment has occurred after four months (in July 2006) and a new equilibrium has been reached after 6 months (in September 2006).[18] Hence, most of the lag in the adjustment to the new equilibrium can be explained by the administrative lag between contract exchange and contract completion.

The next three figures consider the movement of the lower notch from £125,000 to £175,000 on 3 September 2008 (the start of stamp duty holiday) and the subsequent movement back to £125,000 on 1 January 2010 (at the end of stamp duty holiday). When interpreting the findings, it is worth keeping in mind that the start of the holiday was unanticipated while the end of the holiday was anticipated (see section 3.1). Figure 7 shows monthly bunching graphs over a 12-month period

[18] Animated versions of all the figures from this section that show the dynamics more vividly can be found at http://personal.lse.ac.uk/kleven/Downloads/MyPapers/WorkingPapers/best-kleven_landnotches_april2013_videos.pdf

around the beginning of the holiday. It is constructed like the preceding figure, except that we now add estimates of excess bunching b around the two cutoffs in each month.[19] The main findings are the following. First, it takes 3-4 months for bunching at the old £125,000 cutoff to disappear (bunching becomes statistically insignificant for the first time in December 2008), corresponding roughly to the lag between contract agreement and completion. Second, it takes about 3 months for bunching at the new £175,000 cutoff to build up and reach a steady state (bunching b is around 0.9 from November 2008 onwards). Third, although bunching at £175,000 in the winter months of 2008/09 is smaller in absolute terms than bunching at £125,000 in the summer months before the holiday, bunching in proportion to the counterfactual distribution (b)—the right measure of responsiveness—is in fact slightly larger at £175,000. The presence of smaller absolute bunching at £175,000 is a result of seasonality in the housing market with fewer house transactions in the winter than in the summer.[20] The presence of larger relative bunching b at £175,000 is consistent with the fact that this notch is larger than the previous one at £125,000 (tax liability jumps of £1,750 and £1,250 respectively).

Figure 8 turns to the 12-month period around the end of the holiday on 1 January 2010 and is constructed exactly as the preceding figure. It is interesting to see the difference in the speed of adjustment to a tax change that is fully anticipated. First, the bunching at £175,000 vanishes immediately in January of 2010 when this cutoff is no longer a notch point. This shows that buyers and sellers did indeed anticipate the end of the holiday and made sure to complete their housing contracts before the end of December 2009. We see such behavior in the graph for December 2009: there is a large upward shift in the December distribution between £125,000 and £175,000 (even though this is normally a low-season month) and an increase in excess bunching at £175,000. The next section investigates such short-term timing behavior in greater detail. Second, it takes about 2 months for bunching at the new £125,000 cutoff to build up and reach a stable equilibrium (b is roughly constant from February 2010 onwards). While this is faster adjustment than at the start of the holiday, it is not as fast as the disappearance of bunching at the end of the holiday. The implication is that, while buyers and sellers were rushing to *complete* agreed housing contracts below the the £175,000 notch just before the end of the holiday (immediate disappearance of old bunching), they did not to the same degree *agree* (but not complete) housing contracts below the £125,000 notch just before the end of the holiday (slower emergence of new bunching).

Figure 9 summarizes the evidence in the preceding figures by showing the monthly bunching estimate b from January 2007 to January 2011 at the £125,000 cutoff (blue dots) and the £175,000 cutoff (orange crosses) with 95% confidence intervals around each series. The solid vertical lines demarcate the beginning and end of the stamp duty holiday, while the dashed vertical line demarcates the de facto time at which the holiday took full effect given the lag between agreed and completed house purchases. The figure highlights just how sharply house prices react to tax notches and to changes in tax notches even at the monthly level. The level of bunching at the £125,000 cutoff

[19] Animated versions of these figures are online at the address in footnote 18.

[20] Seasonality in the housing market is a well-known phenomenon that has been studied in the macro literature (e.g. Ngai & Tenreyro 2012).

is remarkably constant on each side of the holiday, while the level of bunching at the £175,000 cutoff is constant during the holiday. The steady state level of bunching at £175,000 ($b \approx 0.9$) is larger than at £125,000 ($b \approx 0.6$) as the former notch is larger. Once we account for the built-in sluggishness due to the time it takes to complete a housing contract, the market adjusts to a new stable equilibrium remarkably quickly. We also do not see any difference in price responsiveness during good times and bad times (compare early part of 2007 to the rest of the period).

Compared to recent bunching evidence from labor markets (e.g. Saez 2010; Chetty *et al.* 2011; Kleven & Waseem 2013), the remarkable sharpness of our evidence suggests that behavioral responses in the housing market are much less affected by optimization frictions such as inattention, inertia, etc. Our evidence suggests that agents in the housing market respond precisely and quickly to tax incentives.

5 Estimating Timing and Extensive Margin Responses Using Tax Reforms and Stimulus

5.1 Stimulus: Effects of the Stamp Duty Holiday

We saw in the previous section that house prices responded sharply when the stamp duty holiday moved the bottom notch between £125,000 and £175,000. However, as discussed above, the motivation for the stimulus policy was also to prop up activity levels in the housing market in order to support the real economy both directly (through repairs, renovations, durable goods, and commissions triggered by house transactions) and indirectly through homeowner mobility, general equilibrium spillovers from the housing market, etc. Hence, this section investigates the dynamic effects of the stamp duty holiday on activity levels in the UK housing market, while the next section combines our stimulus estimates with survey data on moving-related household expenditures in order to evaluate the effect on the real economic activity (not including potential multiplier effects).

As described earlier, the stamp duty holiday was an unanticipated stimulus program with a fixed and fully anticipated end date. In the context of the dynamic model in section 2.1, this corresponds to an unanticipated tax cut in period s with no tax changes after period s, and in Proposition 2 we demonstrated that such a policy change has two conceptual effects on the level of activity in the housing market. First, there will be a *timing effect* as some agents who would have transacted a house after period s bring that transaction forward to period s. Second, there will be an *extensive margin effect* as some agents engage in additional house transactions over their lifetime, including house purchases in period s by those who would otherwise never buy (renter/homeowner margin) and house purchases in period s by those who continue to transact as often as they otherwise would have during the rest of their lives (more moving by existing homeowners). Hence, to evaluate fiscal stimulus programs of this kind, it is crucial to obtain estimates not just of the total stimulus effect during the program (timing and extensive margin effects), but also of the degree to which it is driven by timing (all of which will be reversed after program withdrawal) and the length of the horizon over which there is re-timing (which determines the speed of reversal). This section provides compelling evidence on all three questions.

The stamp duty holiday temporarily cut the tax rate from 1% to 0% in the price range £125,000 to £175,000 without changing the tax rate in neighbouring price ranges, presenting us with an ideal opportunity to pursue a difference-in-differences approach. A naïve first cut at this (that we refine shortly) is to compare the evolution over time in transaction volumes in the treated range £125,000–£175,000 to a nearby control range. This is done in Figure 10, which compares the log monthly number of transactions in the treated range £125,000–£175,000 (blue dots) to a control range defined as £175,000–£225,000 (orange crosses). We have normalized the log number of transactions in each month by subtracting the average log number of transactions in the pre-treatment period (the 2 years leading up to the holiday) in order to make visual comparison of the two series easier. The solid vertical lines mark the beginning (3 September 2008) and the end (31 December 2009) of the stamp duty holiday.[21]

The two series display completely parallel trends leading up to the holiday and then begin to diverge precisely when the holiday starts. The positive effect of housing stimulus in the treated range increases during the first months of the holiday and features a sharp spike in the last month as people rushed to take advantage of the stimulus before it expired. After the holiday, there is a sharp dip in the treated series during the first month, but only slight additional reversal thereafter as the treated group is marginally below the control group for about a year and then converges with the control group in the later part of the sample. Taken at face value, this graph implies that housing stimulus gave a large boost to housing market activity during the policy with very weak reversal after the policy (apart from the short-term timing effect shown by the spike and dip right around the stimulus end date).[22] However, we argue that this both overstates the positive impact of the stimulus policy and understates the slump after the end of the policy.

The issue with the analysis in Figure 10 is that treatment assignment (whether a transaction takes place in the £125,000–£175,000 price range) is endogenous to movements across bracket cutoffs. The stamp duty holiday creates an incentive to move into the treated price bracket from

[21] As described in section 3.1, a stamp duty relief scheme was implemented for first-time buyers in the price range £125K–£250K between 25 March 2010 and 24 March 2012 (*after* the end of the stamp duty holiday). Since we are also interested in estimating reversal after the stamp duty holiday, it is important to make sure that the first-time buyers' relief scheme is not a confounding factor during the reversal period. This motivates using a control range (£175K–£225K) just above the treatment range (£125K–£175K), ensuring that both groups fall within the range eligible for first-time buyers' relief and therefore face the same incentive from this scheme. There could still be a concern that the treatment and control range respond differently to the first-time buyer incentive, which would be a confounding factor in the reversal estimates. To alleviate this concern, we drop all transactions claiming first-time buyers' relief throughout the analysis in this section. Including those observations only strengthens our findings below of incomplete reversal after the end of the stamp duty holiday.

[22] Note that the control group also features a (much smaller) spike and dip around the end of the stamp duty holiday. Importantly, this does not reflect that the control group is also responding to the stimulus end date, but is a result of a Christmas/New Year effect whereby individuals rush to complete house transactions before the end of the year (or rather before the Christmas holiday during which the housing market almost shuts down) with an associated slump in activity in January. This timing effect takes place in every year and every price range, and is therefore equally present in both the treatment and control groups. This can be seen in Figure 10 by considering end-of-year cutoffs outside the stamp duty holiday. Appendix Figure A.3 investigates these short-term timing effects in greater detail, including placebo specifications showing that Christmas/New Year bunching is similar in the treatment and control groups in years where the stamp duty holiday is not about to expire.

both sides. At the upper end of the range, the holiday creates a new notch at £175,000 that induces agents to move from a region above the cutoff to a point just below the cutoff (bunching). We have shown in section 4 above that bunching responses at £175,000 do indeed occur, and this increases activity in the treated range compared to the control range. At the lower end, the holiday eliminates the notch at £125,000 and therefore induces bunchers at this cutoff to move back into the hole above the cutoff. We have shown that the disappearance of bunching at £125,000 also occurs, and this further increases activity in the treated range compared to the control range. Hence, the positive effect of housing stimulus in Figure 10 combines the true effect on overall activity levels with endogenous price responses resulting from the change in the location of the notch.

There are two ways of dealing with this endogeneity issue. The simplest way is to widen the treatment range on each side (below £125,000 and above £175,000) in order to ensure that any price manipulation around notches occurs *within* the treatment range and so does not affect measured activity levels in this range. By including transactions outside the tax holiday area in the treatment group, this strategy captures an intent-to-treat effect and therefore understates the impact on the actually treated. We consider this intent-to-treat strategy in Appendix Figure A.4, but here we focus instead on a more sophisticated way of dealing with endogeneity. This strategy exploits the fact that we have monthly bunching estimates of price responses to notches and can therefore directly control for it. That is, we may consider the number of transactions in different price brackets adjusted for the effect of bunching behavior in each month. To be precise, in every month, the estimated bunching mass just below £125,000 is reallocated to the treatment range £125,000-£175,000 while the estimated bunching mass just below £175,000 is reallocated to the control range £175,000-£225,000. By using these bunching-adjusted counts in our difference-in-differences strategy, we avoid bias from selection into treatment.

Figure 11 shows the results from this bunching-adjusted strategy. Panel A shows the normalised logs of the monthly number of transactions in the treatment and control ranges exactly as in Figure 10. It is visually clear that this strategy results in effects of housing stimulus that are qualititatively similar, but considerably smaller, and that there is a stronger lull in activity after the end of the stamp duty holiday. Panel A also suggests that the lull in activity lasts for approximately 12 months, after which the two series are completely parallel again. Panel B shows the cumulative sums of the two series in panel A as well as the cumulative sum of the differences between the two series (in green diamonds) in order to emphasise the effects we are studying. Panel B confirms that the two series track each other before the stimulus, diverge gradually during the stimulus period, and then converge for around 12 months until they revert to their pre-stimulus, parallel trends.

In order to quantify the effects of the stimulus, we run the following regression on a panel of monthly activity levels in price bins of £5,000 (over the range £125K-£225K) between September 2006 and October 2012

$$\begin{aligned} n_{it} &= \alpha_0 Pre_t + \alpha_H Hol_t + \alpha_R Rev_t + \alpha_P Post_t + \alpha_T Treated_i \\ &\quad + \beta_H Hol_t \times Treated_i + \beta_R Rev_t \times Treated_i + \beta_P Post_t \times Treated_i + \nu_{it}, \end{aligned} \tag{17}$$

where n_{it} is the log number of transactions in price bin i and month t, Pre_t is a dummy for the pre-period September 2006–August 2008, Hol_t is a dummy for the stamp duty holiday period September 2008–December 2009, Rev_t is a dummy for the post-holiday reversal period January–December 2010, $Post_t$ is a dummy for the later months January 2011–October 2012, $Treated_i$ is a dummy for the treated price range £125K-£175K, and finally ν_{it} is an error term that we allow to be clustered at the monthly level.[23] The coefficients we are interested in are β_H (positive effect during stimulus) and β_R (negative effect after stimulus due to re-timing).

Panel A of Figure 11 shows our estimates of the coefficients β_H, β_R and β_P. The coefficient $\hat{\beta}_H = 0.20$ (0.022) implies that average monthly activity was approximately 20% higher during the holiday than it would have been in the absence of stimulus. The coefficient $\hat{\beta}_R = -0.08$ (0.032) implies that average monthly activity was about 8% lower in the first year after the stimulus than it otherwise would have been. Together, these estimates imply that 31% of the additional activity created by the stimulus program was a timing response by people bringing forward their purchases in order to benefit from the tax cut, while the remaining 69% was a permanent, extensive margin effect.[24] Since the end date of the reversal period (December 2010) was chosen visually as the point at which the two series become parallel again, there might be a concern that our estimate of total reversal is sensitive to the choice of this end date. In order to address this, Panel C of Figure 11 shows how this result changes as a different end date is chosen. The green diamonds show estimates of total reversal as a share of total stimulus as the regression (17) is performed using different reversal period cutoffs, and the grey shaded area depicts the 95% confidence interval around these estimates.[25] The reversal estimate is not sensitive to this choice, never rising above 40%, and we can always confidently reject the presence of full reversal.

When considering the simpler intent-to-treat strategy described above (see Figure A.4), the effects are qualitatively similar but quantitatively somewhat weaker as one would expect. The intent-to-treat strategy produces larger reversal as a share of stimulus (between 40-50%) than the bunching-adjusted strategy, but we can still reject full reversal in all specifications.

It is important to note that our quasi-experimental micro approach to evaluating stimulus policy does not capture potential general equilibrium or multiplier effects. If the program had a salutary effect on the housing market and macroeconomy as a whole, this effect would be present in both treatment and control groups and therefore not show up in our difference-in-differences estimates. Besides general equilibrium and multiplier effects, a source of spillovers between treatments and

[23] Since we run the difference-in-differences regression (17) using bunching-adjusted activity levels in £5K bins, we have to reallocate bunching mass below the two cutoffs to specific £5K bins above the cutoffs. We reallocate bunching mass below a cutoff to the five bins above the cutoff in proportion to the amount of missing mass (difference between the estimated counterfactual mass and the observed mass) in each bin. Furthermore, since activity levels are adjusted using *estimated* bunching at the thresholds, we are introducing measurement error to our dependent variable coming from misspecification of the counterfactual when calculating the amount of bunching at £125K and £175K. However, since this measurement error is effectively noise in the dependent variable, it does not cause bias in our estimates, but simply increases our standard errors.

[24] The estimate of total reversal as a share of total stimulus is calculated as $-\left(12\hat{\beta}_R\right) / \left(16\hat{\beta}_H\right)$.

[25] The point estimates are calculated as $-\left(\sum_t Rev_t \times \hat{\beta}_R\right) / \left(16\hat{\beta}_H\right)$, where $\sum_t Rev_t$ denotes the length of the reversal period in the particular regression. Standard errors are computed by the delta method.

controls may arise from *real estate chains*, i.e. linked house transactions whereby someone selling a house in the treatment range is simultaneously buying a house in the control range. Bias from chain effects can be reduced or eliminated by considering control ranges further away from the treatment range, but such strategies create other problems with comparability and parallel trends. The key thing to realize is that potential chain effects unambiguously work against us and create attenuation bias, and so the (large) stimulus estimates we obtain by comparing neighboring price ranges are, if anything, conservative.

Our stimulus findings—especially the absence of full reversal in the UK housing market—stand in contrast to the findings by Mian & Sufi (2012) based on a short (1 month) auto purchase subsidy scheme in the US. While they find that the entire effect of the stimulus is undone by swift reversal after the withdrawal of the program, we find a sizable permanent effect of stimulus in a market viewed by many as pivotal to macroeconomic fluctuations. The permanent effect reflects that homeowners make additional moves between houses that would otherwise not have happened. The contrast between our findings and those of Mian & Sufi (2012) may suggest that stimulus policies that are of extremely short duration, such as the one they study, do not give households sufficient time to respond along the extensive margin and therefore have only short-term timing effects. Hence, our findings highlight the importance of the length of the stimulus program. Of course, while the strength of reversal is important for evaluating stimulus, it does not by itself indict or validate such policies as their key rationale is to create more economic activity when the economy is slack (even if this comes at the expense of less economic activity when the economy is tight). The next section provides a rough estimation of the immediate increase in real economic activity created by the UK housing stimulus program.

5.2 Immediate Effects of Stimulus on Real Economy

While the previous section established that the stamp duty holiday had a large effect on transaction volume in the housing market (and therefore on household mobility), a motivation for the policy was also to stimulate real economic activity through larger household spending driven by the complementarities between moving house and spending. Investigating the effect of the UK housing stimulus program on household spending also allows for a comparison between our findings and previous work on the consumer spending effect of fiscal stimulus programs such as income tax rebates (e.g. Shapiro & Slemrod 2003a,b; Johnson *et al.* 2006; Agarwal *et al.* 2007; Kreiner *et al.* 2012).

A fully rigorous analysis of the effects of housing transactions on expenditure is beyond the scope of this paper, but we perform some back-of-the-envelope calculations to shed light on the likely magnitude of these effects. Using data from the UK Living Costs and Food Survey, we estimate in Appendix Table A.1 that households spend roughly an additional 1.6% of the value of their home on repairs, improvements, furnishings, appliances and other durable goods when they move. This is a conservative estimate compared to similar calculations for the US (Siniavskaia 2008; Zillow.com 2012). Estate agents' fees average 1.98% of the value of the house and other commissions come to 1.24%, giving an estimate of the total expenditure accompanying a house transaction of

4.8% of the house value. Denoting this estimate by ϕ, the immediate impact of the policy on GDP is $\Delta GDP = \phi h_v^m \Delta n$ where h_v^m is the average value of houses bought during the stimulus, and Δn is the number of additional transactions resulting from the policy. To arrive at an estimate of the effectiveness of the policy that is comparable to other stimulus policies, we scale it by the foregone tax revenue, $\Delta Tax = \tau_0 h_v^m n_0$ where $\tau_0 = 1\%$ is the pre-stimulus tax rate, and n_0 is the counterfactual number of transactions in the price range affected by the stimulus. In the previous section, we estimated $\Delta n/n_0$ to be $\beta_H = 0.20$, and so we arrive at an estimate of the effect on economic activity per dollar of tax cut equal to $\Delta GDP/\Delta Tax = \phi\beta_H = 0.96$.[26]

These calculations suggest that the stamp duty holiday not only successfully stimulated housing market activity, but also provided a significant boost to real economic activity through the complementarities between moving house and consumer spending. These rough calculations exclude other indirect effects, for example labor market effects of increased mobility and Keynesian multiplier effects. As a benchmark, the previous work cited above on fiscal stimulus through income tax rebates found significantly smaller effects on consumer spending (between 0.2-0.7 dollars of spending per dollar of tax cut, as opposed to about 1 dollar of spending here). Overall, our findings suggest that transaction tax cuts (or subsidies) can be very effective at stimulating both housing market activity and real economic activity during downturns.

5.3 Permanent Reform: Effects of the 2005 Tax Cut

On 16 March 2005, the bottom notch was moved from £60,000 to £120,000. The reform took effect immediately after its announcement, and while a reform of this kind had been expected, the exact timing and details were not. Since this was a permanent reform, studying its impact over an extended period after its implementation will allow us to analyze the extensive margin effects of permanent reforms (since potential timing effects will only affect the months just after the reform). It is also worth noting that this reform was implemented during the height of the housing market boom, in sharp contrast to the stamp duty holiday implemented at the bottom of the recession.

The reform cut the tax from 1% to 0% over the price range £60,000 to £120,000 while leaving the tax unchanged in neighbouring price ranges, which again presents us with the opportunity to pursue a difference-in-differences strategy. The issue that treatment assignment is endogenous to price responses to the movement of the notch is present in exactly the same way as for the stamp duty holiday, and so we address it in the same way by using monthly bunching estimates to account for price responses. Figure 12 shows the results from our bunching-adjusted difference-in-differences strategy. Panel A shows the normalised log counts of monthly transaction volumes in the treatment range £60,000–£120,000 (blue circles) and the control range £120,000–£180,000 (orange crosses) together with the estimated treatment effect from a regression analogous to equation (17), while panel B shows the cumulative sums of the normalised log counts in the treatment and control ranges. As panel A shows, the treatment and control ranges were parallel in the months leading up to the

[26] Appendix Table A.1 shows details of the calculations and their sensitivity to using the intent-to-treat estimate of β_H discussed in the previous subsection as well as an alternate estimate of households' additional expenditure.

reform, and then diverged sharply immediately following the reform. The estimated coefficient $\hat{\beta}_P = 0.23$ (0.018) implies that this permanent reform increased monthly transaction volumes by approximately 23% on average. This effect is considerably larger than the permanent effect of the stamp duty holiday stimulus, consistent with the hypothesis above that the permanent effect of tax changes is increasing in the length of the time horizon of the policy.

6 Conclusion

This paper has studied the impact of property transaction taxes on the housing market, using unique administrative data on every property transaction in the UK from 2004-2012 and compelling quasi-experimental variation created by notches, tax reforms, and stimulus. We have presented evidence on the effects of transaction taxes on house prices as well as on the timing and volume of house purchases, including an analysis of the dynamics of adjustment to both anticipated and unanticipated tax changes. The overall finding is that prices and activity in the housing market respond sharply and quickly to transaction taxes in the way that economic theory predicts. Our study of transaction taxes in the property market could also have implications for the potential effects of transaction taxes in other asset markets, including transaction taxes on financial assets that have been discussed widely in recent years.

Our findings from the 2008-2009 stamp duty holiday contribute to the scant micro evidence on the effectiveness of fiscal stimulus and, in particular, present some of the first evidence on the effectiveness of using temporary tax changes to stimulate the housing market during economic downturns. The 16-month stamp duty holiday was enormously successful in stimulating housing market activity, increasing the volume of house transactions by as much as 20% in the short run (due to timing and extensive responses) followed by a smaller slump in activity after the policy is withdrawn (as the timing effect is cancelled out). Due to the complementarities between moving house and consumer spending, these stimulus effects translate into GDP effects that are considerably larger than what has been found for other forms of fiscal stimulus such as income tax rebates. The successfulness of stamp duty stimulus is a result of the large distortions created by the tax in the first place.

References

Adelino, Manuel, Schoar, Antoinette, & Severino, Felipe. 2012. *Credit Supply and House Prices.* NBER Working Paper no. 17832.

Agarwal, Sumit, Liu, Chunlin, & Souleles, Nicholas S. 2007. The Reaction of Consumer Spending and Debt to Tax Rebates – Evidence From Consumer Credit Data. *Journal of Political Economy*, **115**, 986–1019.

Auerbach, Alan J. 1988. Capital Gains Taxation in the United States: Realizations, Revenue, and Rhetoric. *Brookings Papers on Economic Activity*, **19**, 595–638.

Benjamin, John D., Coulson, N. Edward, & Yang, Shiawee X. 1993. Real Estate Transfer Taxes and Property Values: The Philadelphia Story. *Journal of Real Estate Finance and Economics*, **7**, 151–157.

BESLEY, TIMOTHY, MEADS, NEIL, & SURICO, PAOLO. 2011. *The Incidence of a Transactions Tax: Evidence from a Tax Holiday.* Working Paper, London School of Economics.

BURMAN, LEONARD E., & RANDOLPH, WILLIAM C. 1994. Measuring Permanent Responses to Capital-Gains Tax Changes in Panel Data. *American Economic Review*, **84**, 794–809.

CHETTY, RAJ, FRIEDMAN, JOHN, OLSEN, TORE, & PISTAFERRI, LUIGI. 2011. Adjustment Costs, Firm Responses, and Micro vs. Macro Labor Supply Elasticities: Evidence from Danish Tax Records. *Quarterly Journal of Economics*, **126**, 749–804.

CUNNINGHAM, CHRISTOPHER R., & ENGELHARDT, GARY V. 2008. Housing Capital-Gains Taxation and Homeowner Mobility: Evidence From the Taxpayer Relief Act of 1997. *Journal of Urban Economics*, **63**, 803–815.

DACHIS, BEN, DURANTON, GILLES, & TURNER, MATTHEW A. 2012. The Effects of Land Transfer Taxes on Real Estate Markets: Evidence From a Natural Experiment in Toronto. *Journal of Economic Geography*, **12**, 327–354.

FELDSTEIN, MARTIN, SLEMROD, JOEL, & YITZHAKI, SHLOMO. 1980. The Effects of Taxation on the Selling of Corporate Stock and the Realization of Capital Gains. *Quarterly Journal of Economics*, **94**, 777–791.

GLAESER, EDWARD L., GOTTLIEB, JOSHUA D., & GYOURKO, JOSEPH. 2010. *Can Cheap Credit Explain the Housing Boom.* NBER Working Paper no. 16230.

HIMMELBERG, CHARLES, MAYER, CHRISTOPHER, & SINAI, TODD. 2005. Assessing High House Prices: Bubbles, Fundamentals and Misperceptions. *Journal of Economic Perspectives*, **19**, 67–92.

JOHNSON, DAVID S., PARKER, JONATHAN A., & SOULELES, NICHOLAS S. 2006. Household Expenditure and the Income Tax Rebates of 2001. *American Economic Review*, **96**, 1589–1610.

KLEVEN, HENRIK, & WASEEM, MAZHAR. 2013. Using Notches to Uncover Optimization Frictions and Structural Elasticities: Theory and Evidence from Pakistan. *Quarterly Journal of Economics*, **128**, 669–723.

KLEVEN, HENRIK, KREINER, CLAUS THUSTRUP, & SAEZ, EMMANUEL. 2009. *Why Can Modern Governments Tax So Much? An Agency Model of Firms as Fiscal Intermediaries.* NBER Working paper 15218.

KLEVEN, HENRIK, LANDAIS, CAMILLE, SAEZ, EMMANUEL, & SCHULTZ, ESBEN. 2013. Migration and Wage Effects of Taxing Top Earners: Evidence from the Foreigners' Tax Scheme in Denmark. *Quarterly Journal of Economics*, forthcoming.

KOPCZUK, WOJCIECH, & MUNROE, DAVID. 2013. *Mansion Tax: The Effect of Transfer Taxes on Residential Real Estate Market.* Mimeo: Columbia University.

KREINER, CLAUS THUSTRUP, LASSEN, DAVID DREYER, & LETH-PETERSEN, SØREN. 2012. *Consumer Responses to Fiscal Stimulus Policy and Households' Cost of Liquidity.* CEPR Working Paper no. 9161.

MIAN, ATIF, & SUFI, AMIR. 2009. The Consequences of Mortgage Credit Expansion: Evidence from the U.S. Mortgage Default Crisis. *Quarterly Journal of Economics*, **124**, 1449–1496.

MIAN, ATIF, & SUFI, AMIR. 2012. The Effects of Fiscal Stimulus: Evidence From the 2009 Cash For Clunkers Program. *Quarterly Journal of Economics*, **127**, 1107–1142.

NGAI, L. RACHEL, & TENREYRO, SILVANA. 2012. *Hot and Cold Seasons in the Housing Market.* mimeo: London School of Economics.

POTERBA, JAMES M. 1984. Tax Subsidies to Owner-Occupied Housing: An Asset-Market Approach. *Quarterly Journal of Economics*, **99**, 729–752.

POTERBA, JAMES M. 1992. Taxation and Housing: Old Questions, New Answers. *American Economic Review, Papers and Proceedings*, **82**, 237–242.

POTERBA, JAMES M., & SINAI, TODD. 2008. Tax Expenditures for Owner-Occupied Housing: Deductions for Property Taxes and Mortgage Interest and the Exclusion of Imputed Rental Income. *American Economic Review, Papers and Proceedings*, **98**, 84–89.

ReallyMoving. 2012. *Moving Costs Report September 2012*. http://www.reallymoving.com.

Rosen, Harvey S. 1985. Housing Subsidies: Effects on Housing Decisions, Efficiency, and Equity. *In: Handbook of Public Economics, vol.1*.

Saez, Emmanuel. 2010. Do Taxpayers Bunch at Kink Points? *American Economic Journal: Economic Policy*, **2**(3).

Saez, Emmanuel, Slemrod, Joel, & Giertz, Seth. 2012. The Elasticity of Taxable Income with Respect to Marginal Tax Rates: A Critical Review. *Journal of Economic Literature*, **50**, 3–50.

Shan, Hui. 2011. The Effect of Capital Gains Taxation on Home Sales: Evidence From the Taxpayer Relief Act of 1997. *Journal of Public Economics*, **95**, 177–188.

Shapiro, Matthew D., & Slemrod, Joel. 2003a. Consumer Responses to Tax Rebates. *American Economic Review*, **93**, 381–396.

Shapiro, Matthew D., & Slemrod, Joel. 2003b. Did the 2001 Tax Rebate Stimulate Spending? Evidence from Taxpayer Surveys. *Tax Policy & The Economy*, **17**, 83–109.

Siniavskaia, Natalia. 2008. *Spending Patterns of Home Buyers*. Report for HousingEconomics.com.

Slemrod, Joel, Weber, Caroline, & Shan, Hui. 2012. *The Lock-In Effect of Housing Transfer Taxes: Evidence From a Notched Change in D.C. Policy*. mimeo: University of Michigan.

van Ommeren, Jos, & van Leuvensteijn, Michiel. 2005. New Evidence of the Effect of Transaction Costs on Residential Mobility. *Journal of Regional Science*, **45**, 681–702.

Zillow.com. 2012. *Mover Study*. http://www.zillowblog.com.

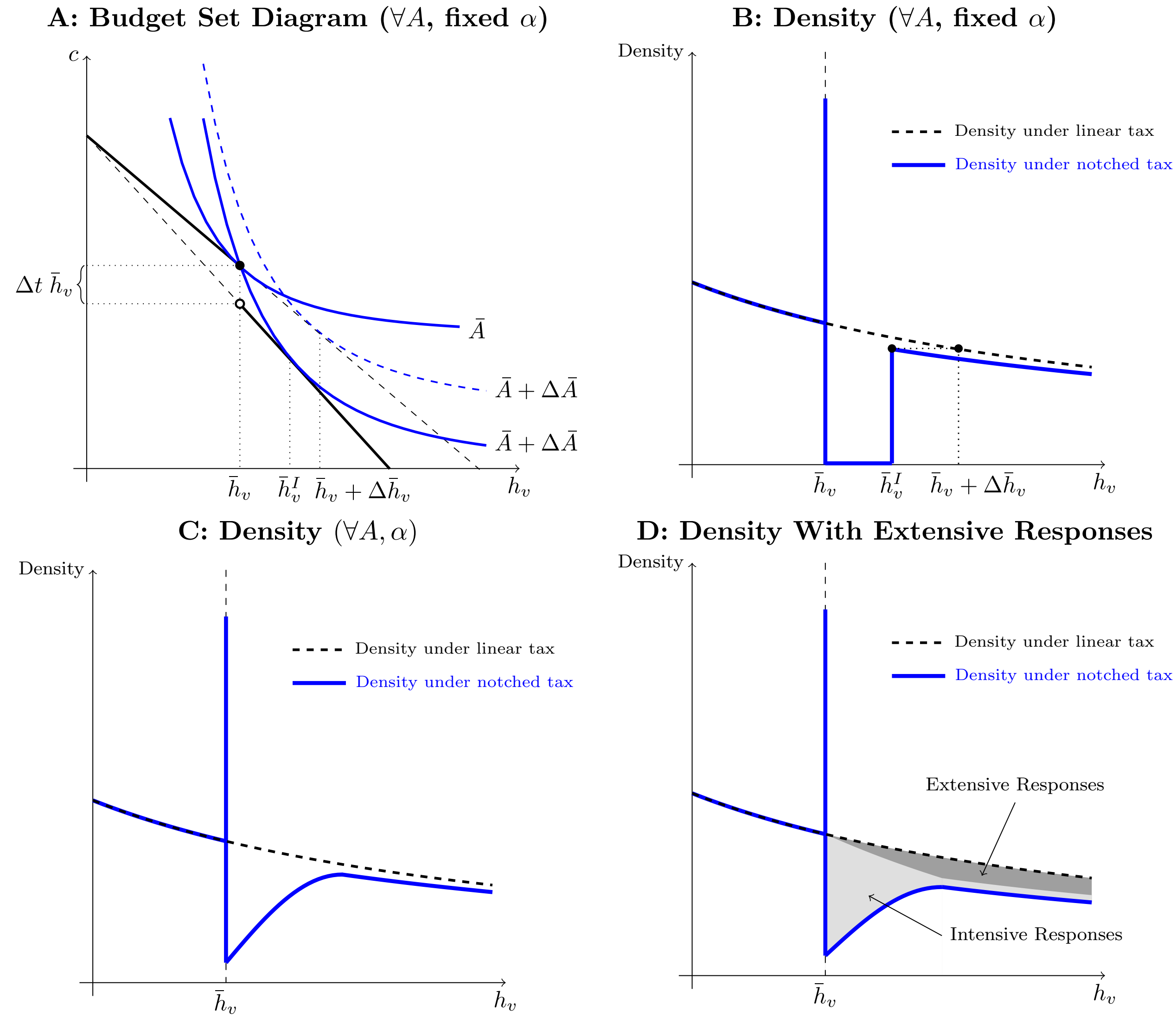
Zodrow, George R. 2001. Reflections on the New View and the Benefit View of the Property Tax. *In: Property Taxation and Local Government Finance*.

Table 1: Residential Property Tax Notches

<table>
<tr><th>Price Range \ Date Range</th><th>1 Dec 2003 to 16 Mar 2005</th><th>17 Mar 2005 to 22 Mar 2006</th><th>23 Mar 2006 to 2 Sep 2008</th><th>3 Sep 2008 to 31 Dec 2009</th><th>1 Jan 2010 to 5 Apr 2011</th><th>6 Apr 2011 to 21 Mar 2012</th><th>22 Mar 2012 to April 2013</th></tr>
<tr><td>0 - £60K</td><td>0</td><td rowspan="2">0</td><td rowspan="3">0</td><td rowspan="4">0</td><td rowspan="3">0</td><td rowspan="3">0</td><td rowspan="3">0</td></tr>
<tr><td>£60K - £120K</td><td rowspan="4">1</td></tr>
<tr><td>£120K - £125K</td><td rowspan="3">1</td></tr>
<tr><td>£125K - £175K</td><td rowspan="2">1</td><td rowspan="2">1</td><td rowspan="2">1</td><td rowspan="2">1</td></tr>
<tr><td>£175K - £250K</td><td>1</td></tr>
<tr><td>£250K - £500K</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>£500K - £1000K</td><td rowspan="3">4</td><td rowspan="3">4</td><td rowspan="3">4</td><td rowspan="3">4</td><td rowspan="3">4</td><td>4</td><td>4</td></tr>
<tr><td>£1000K - £2000K</td><td rowspan="2">5</td><td>5</td></tr>
<tr><td>£2000K - ∞</td><td>7</td></tr>
</table>

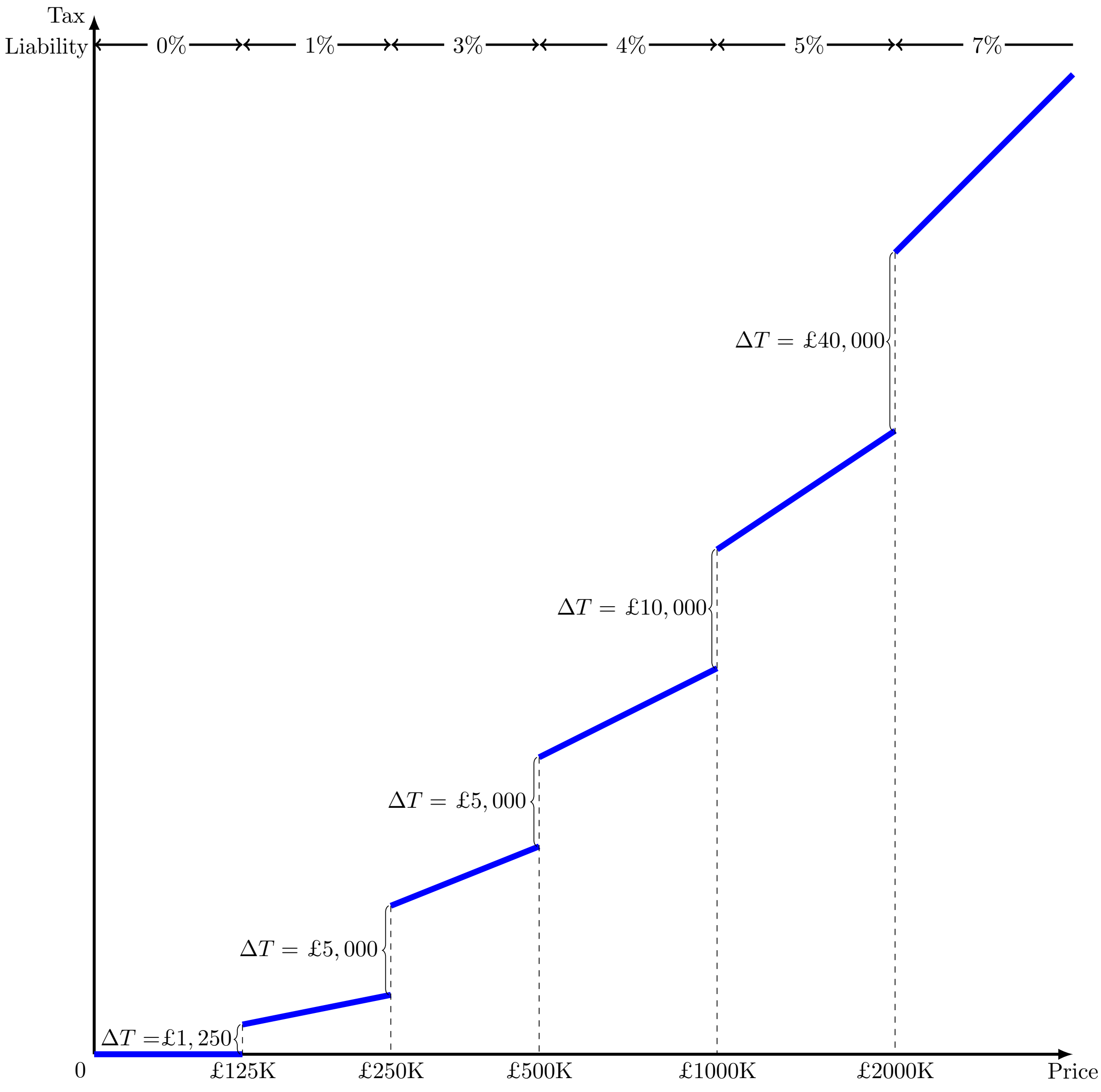
Notes: The table shows how the stamp duty land tax schedule for residential property has varied over time. Each column represents a time period during which the tax schedule was constant. The rows represent price ranges, and the entry in each cell is the tax rate that applies to that price range in the time period.

Figure 1: Theoretical Figures



Notes: Figure 1 illustrates the implications of a notched transaction tax schedule in a budget set diagram (Panel A) and density distribution diagrams (Panels B-D). The budget set diagram in panel A (depicting preferences as in equation (1) and the budget set given by equation (2) in (h_v, c)-space) illustrates intensive responses among individuals with heterogeneous housing preferences A, but a specific demand elasticity α. The notch creates bunching at the cutoff $\overline{h}_v$ by all individuals in a preference range $(\overline{A}, \overline{A}+\Delta\overline{A})$, who would have bought houses on the segment $(\overline{h}_v, \overline{h}_v+\Delta\overline{h}_v)$ in the absence of the notch. The marginal bunching individual at $\overline{A}+\Delta\overline{A}$ is indifferent between the notch point $\overline{h}_v$ and the best interior location $\bar{h}_v^I$. No individual is willing to locate between $\overline{h}_v$ and $\bar{h}_v^I$, and hence this range is completely empty. The density of property values corresponding to the budget set diagram (all A, one specific α) is shown in Panel B. Since the behavioral response in Panels A-B depends on the size of the demand elasticity α (and converges to zero for completely price inelastic buyers), the density in the full population (all A, α) can be illustrated as in Panel C where some individuals are willing to buy just above the notch point. In addition to intensive responses, the notch creates extensive responses above the cutoff by individuals close to the indifference point between buying and not buying ($q \approx q^*$, where q^* is defined in equation (4)). However, such extensive responses will be negligible *just* above the cutoff. Intuitively, if an individual prefers buying a house slightly above $\overline{h}_v$ in the absence of the notch, then he will be better off by buying a house at $\overline{h}_v$ (which is almost as good) than not buying at all in the presence of the notch. This reasoning implies that extensive responses affect the density as illustrated in Panel D.

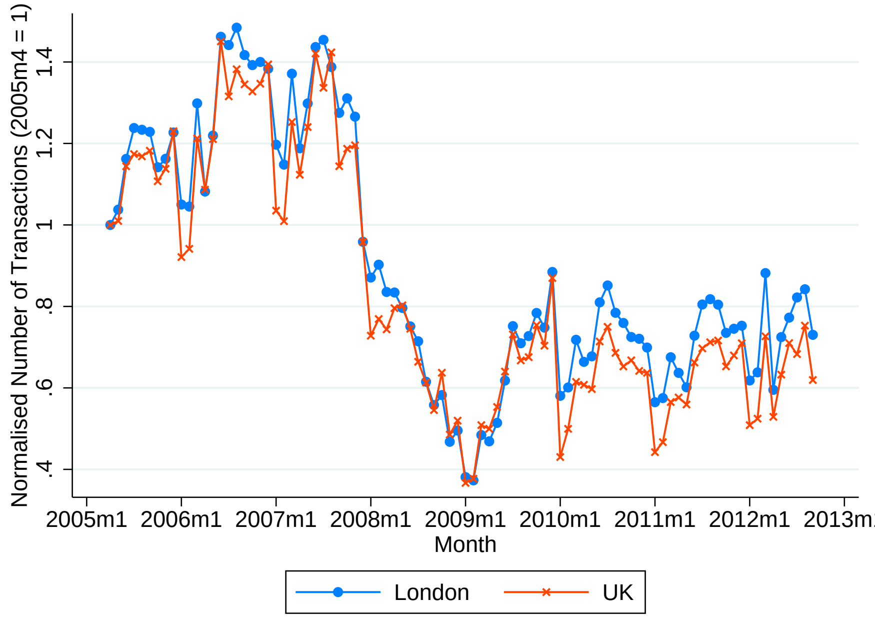
Figure 2: Tax Schedule in March 2013



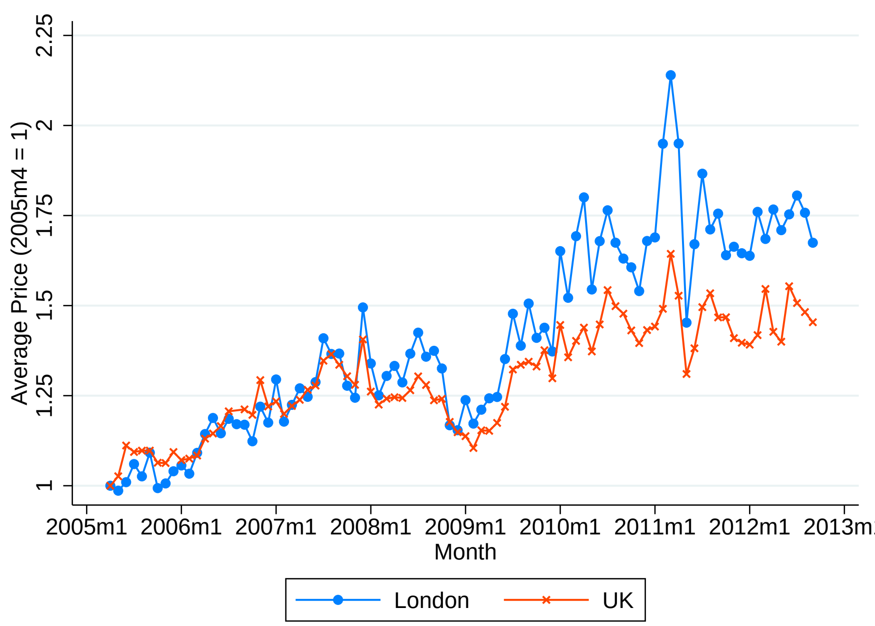
Notes: Figure 2 shows the stamp duty land tax schedule for residential properties in place in March 2013 graphically as the solid blue line. The tax liability jumps discretely at the notches at £125,000, £250,000, £500,000, £1,000,000 and £2,000,000. Within the brackets defined by these notches, the tax rate is constant, and applied to the whole transaction price at the rates shown along the top of the figure.

Figure 3: Summary Statistics

A: Number of Transactions



B: Average Price



Notes: Panel A shows the monthly average price of property transactions relative to the average price in April 2005 in London (blue circles) and the U.K. (orange crosses). The average price of property transactions in London during the period April 2005 - October 2012 was £345,360 and the average price in the U.K. during our data period was £199,479. Panel B shows the monthly total number of property transactions relative to the number that took place in April 2005 in London (blue circles) and the U.K. (orange crosses). The average monthly number of property transactions in London during the period April 2005 - October 2012 was 12,955 while the average monthly number of property transactions in this period in the U.K. was 103,561.

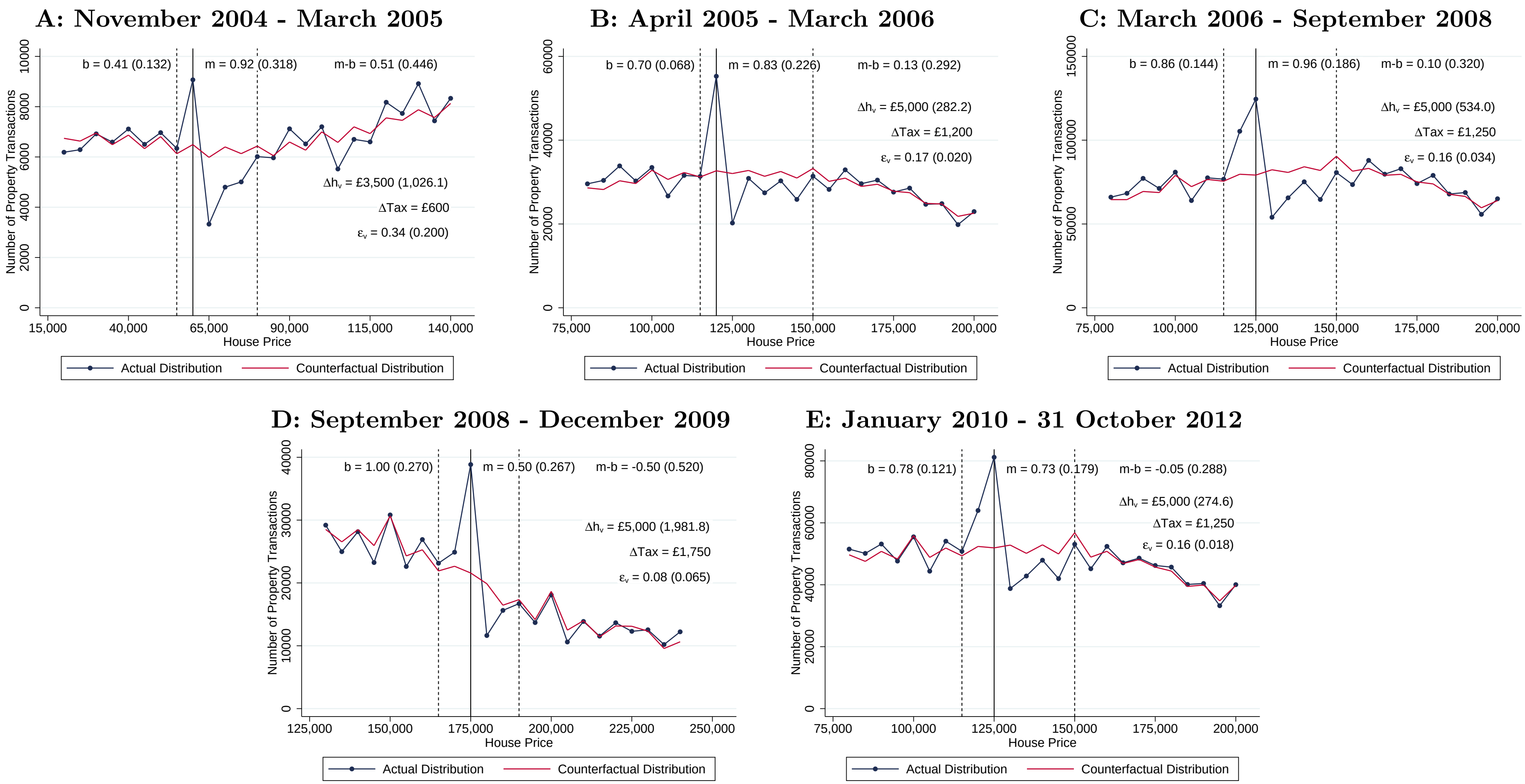
Figure 4: Bunching and Holes Around the Notches That Remain Constant

A: Notch at £250,000

B: Notch at £500,000

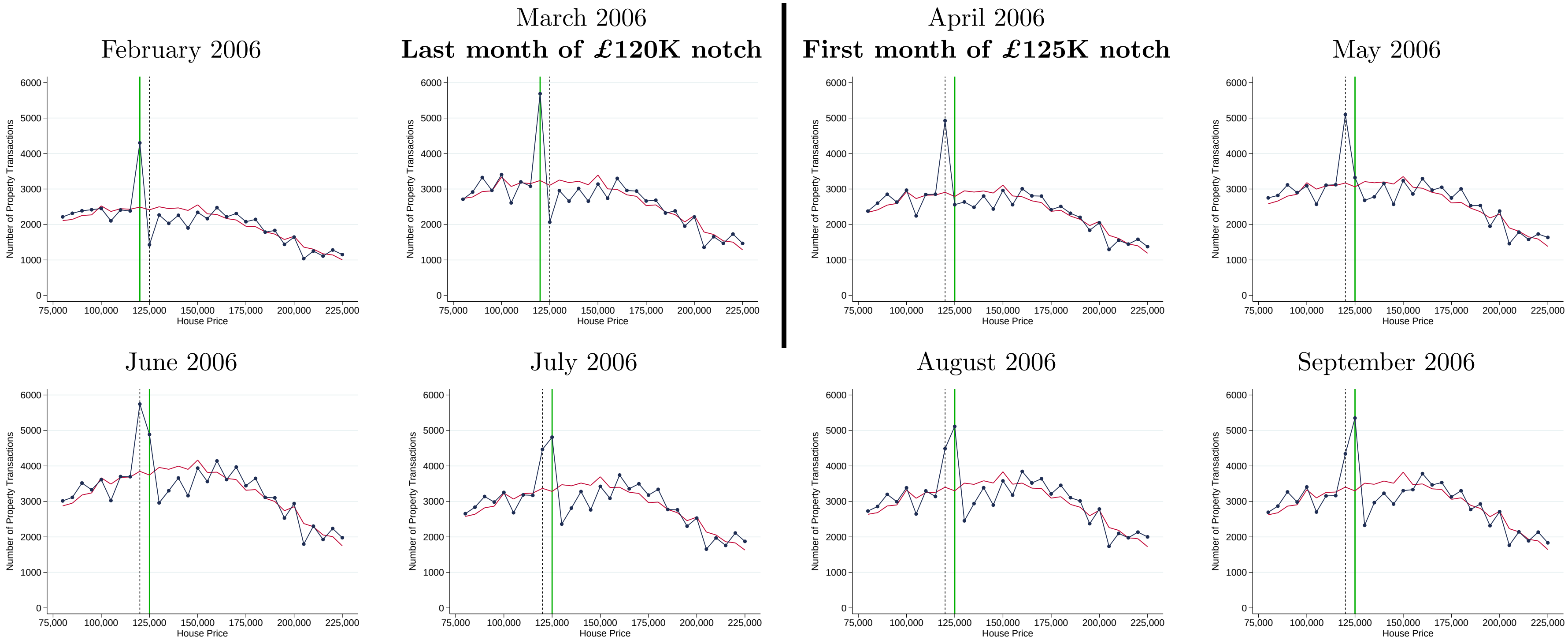
Notes: The figure shows the observed density of property transactions (blue dots) and our estimated counterfactual density (red line) around the notch at £250,000 where the tax liability jumps by £5,000 (from 1% to 3% of the transaction price) in panel A and around the notch at £500,000 where the tax liability jumps by £5,000 again (from 3% to 4% of the transaction price). The data used for these estimates excludes transactions that claim relief from the stamp duty land tax (except for those claiming first-time buyers' relief) as the regular tax schedule does not apply to these transactions. The counterfactual density is estimated as in equation (16), using bins £100 pounds wide and a polynomial of order 5. The vertical dashed lines denote the upper and lower bounds of the excluded region around the notch. The upper bound of the excluded region is chosen as the point where the observed density changes slope from positive to negative. The estimate of equation (16) controls for round number bunching at multiples of £500, £1,000, £5,000, £10,000, £25,000 and £50,000. Both the empirical and the counterfactual density are shown aggregated up to bins £5,000 wide. b is our estimate of the excess mass just below the notch scaled by the average counterfactual frequency in the excluded range, with its standard error shown in parentheses. m is our estimate of the missing mass above the notch scaled by the average counterfactual frequency in the excluded range, with its standard error shown in parentheses. $m - b$ is our estimate of the difference between the missing mass and the bunching mass, again with its standard error in parentheses. The figures also show the average house value change created by the notch, and the tax liability change at the notch. All standard errors are obtained by bootstrapping the procedure 200 times.

Figure 5: Bunching and Holes Around the Lower Notch



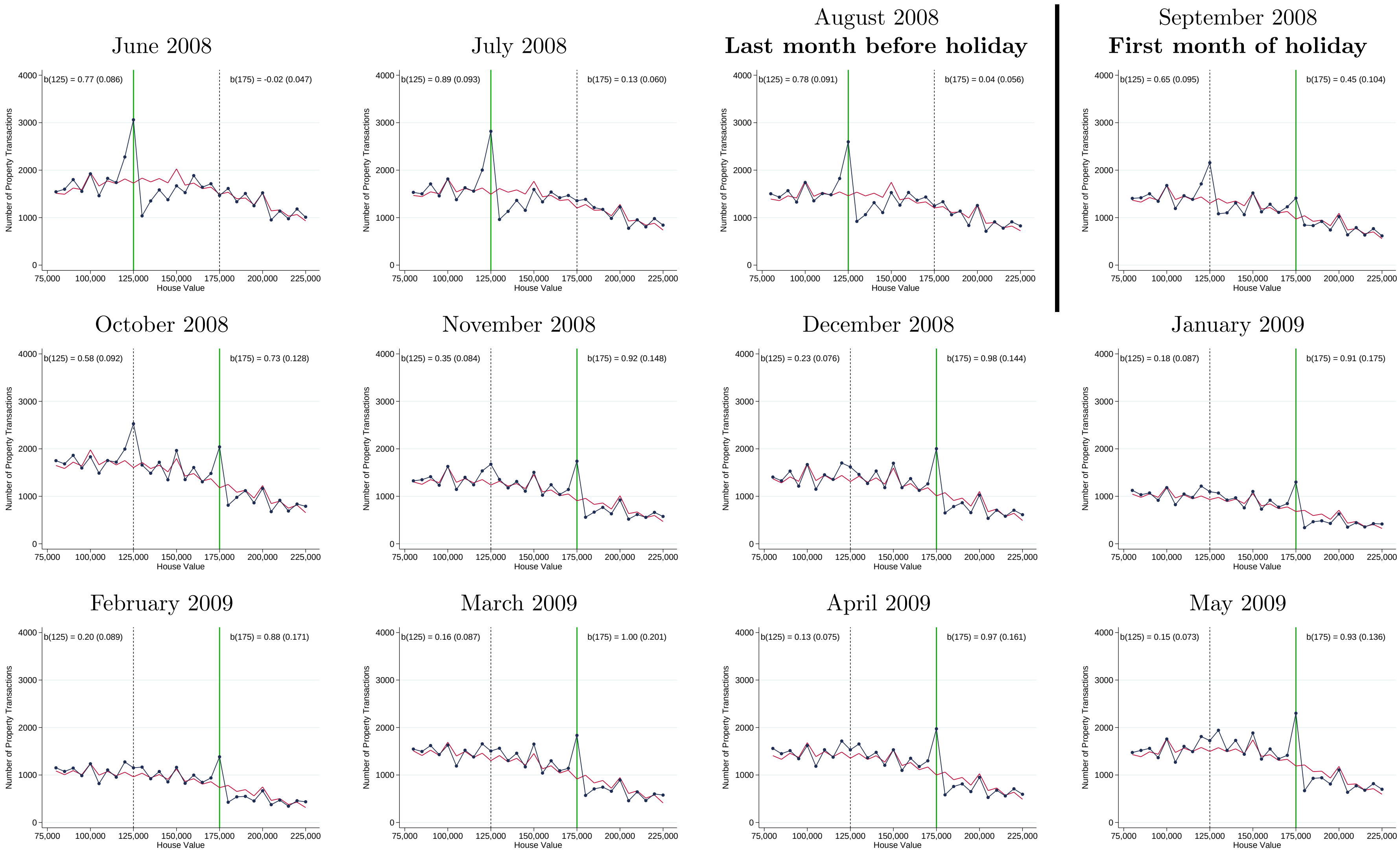
Notes: The figure shows the observed density of property transactions (blue dots) and our estimated counterfactual density (red line) around the lower notch in the residential property tax schedule where the tax liability jumps from 0 to 1% of the transaction price. Panel A shows the period 1 November 2004 to 16 March 2005 when the notch was at £60,000. Panel B shows the period 17 March 2005 to 22 March 2006 when the notch was at £120,000. Panel C shows the period 23 March 2006 to 2 September 2008 when the notch was at £125,000. Panel D shows the period 3 September 2008 to 31 December 2009 when the notch was at £175,000. Panel E shows the period 1 January 2009 to 31 October 2012 when the notch was at £125,000. The data used for these estimates excludes transactions that claim relief from the stamp duty land tax (excepting those who claimed first time buyers' relief) as the regular tax schedule does not apply to these transactions. The counterfactual density is estimated as in equation (16), using bins £100 pounds wide and a polynomial of order 5 in panels A, C, D and E and of order 4 in panel B. The vertical dashed lines denote the upper and lower bounds of the excluded region around the notch. The upper bound of the excluded region is chosen as the point where the observed density stops increasing and becomes decreasing (apart from spikes at round numbers). The estimate of equation (16) controls for round number bunching at multiples £500, £1,000, £5,000, £10,000, £25,000 and £50,000. Both the empirical and the counterfactual density are shown aggregated up to bins £5,000 wide. b is our estimate of the excess mass just below the notch scaled by the counterfactual density at the notch, with its standard error shown in parentheses. m is our estimate of the missing mass above the notch scaled by the counterfactual density at the notch, with its standard error shown in parentheses. $m - b$ is our estimate of the difference between the missing mass and the bunching mass, again with its standard error in parentheses. The figures also show the average house value change created by the notch, and the tax liability change at the notch. All standard errors are obtained by bootstrapping the procedure 200 times.

Figure 6: Dynamics of Bunching at Bottom Notch around March 2006



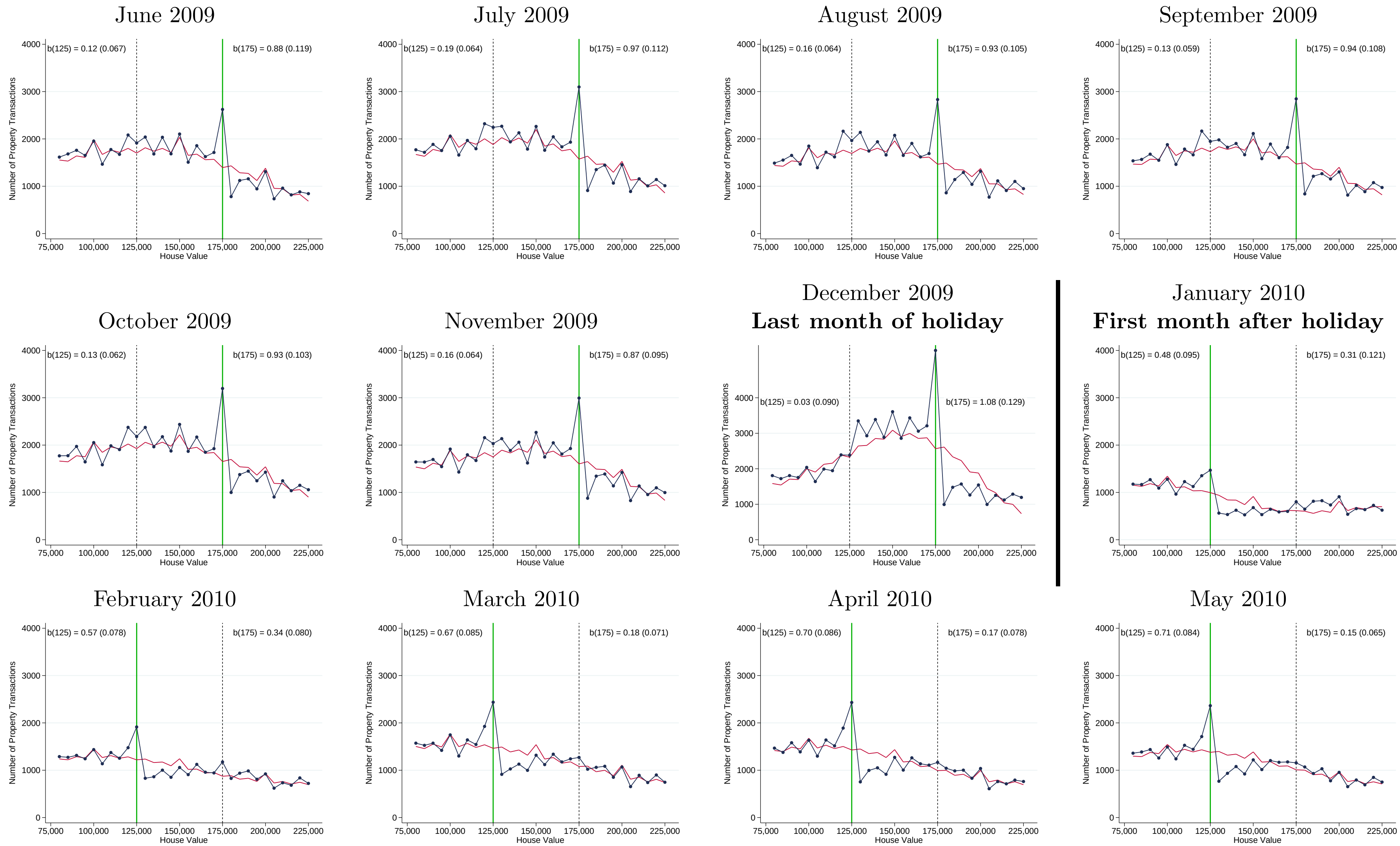
Notes: The figure shows the observed density of property transactions (blue dots) and our estimated counterfactual density (red line) in the region £75,000 – £225,000 separately for each month. On 23 March 2006, the bottom notch moved from £120,000 to £125,000. The estimation of the counterfactual is as described in section 4.1 and in the notes to figures 4 & 5. The estimation excludes data in the regions £115,000 – 140,000 and £170,000 – £190,000 and uses a polynomial of order 5. Animated versions of these figures that show the dynamics more vividly can be found at http://personal.lse.ac.uk/kleven/Downloads/MyPapers/WorkingPapers/best-kleven_landnotches_april2013_videos.pdf

Figure 7: Dynamics of Bunching Around the Beginning of Stamp Duty Holiday



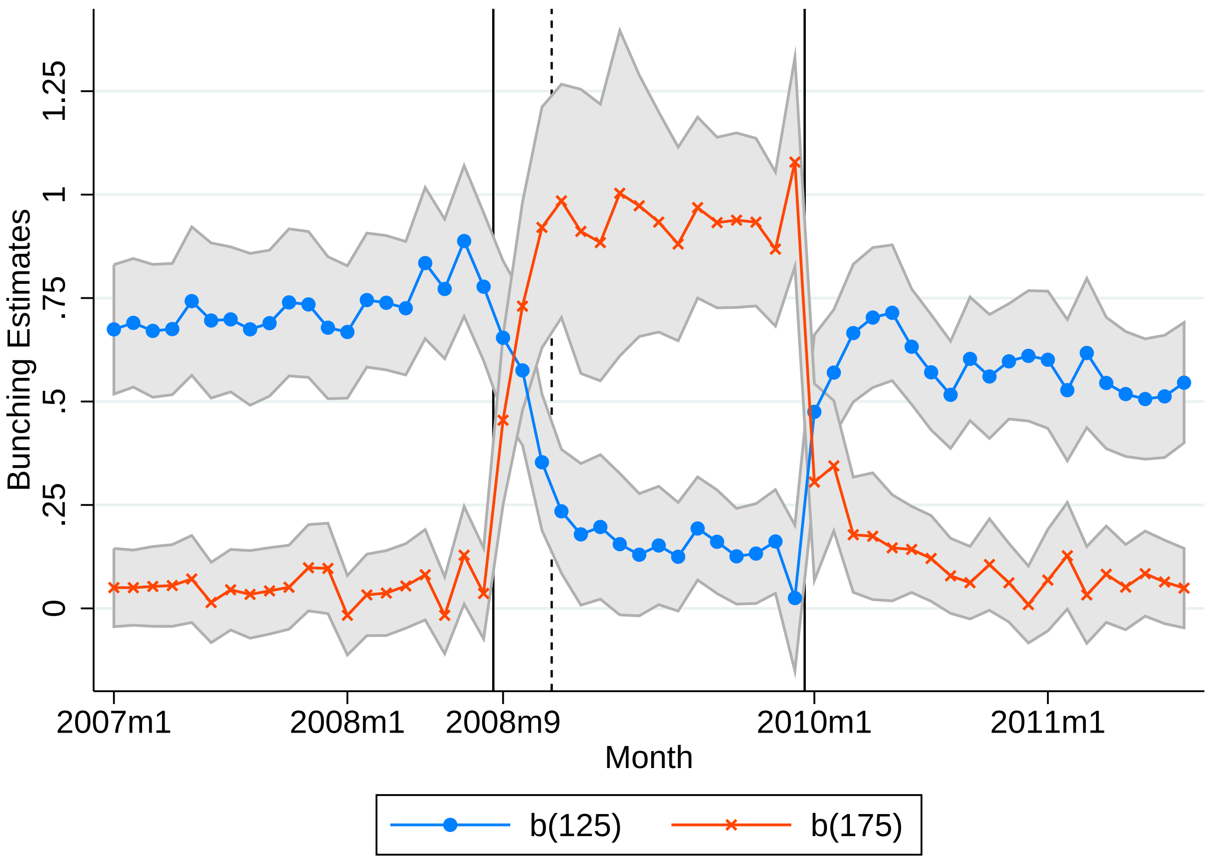
Notes: The figure shows the observed density of property transactions (blue dots) and our estimated counterfactual density (red line) in the region £75,000 – £225,000 separately for each month. On 3 September 2008, the bottom notch was moved unexpectedly from £125,000 to £175,000. The estimation of the counterfactual is as described in section 4.1 and in the notes to figures 4 & 5. The estimation excludes data in the regions £115,000 – 140,000 and £170,000 – £190,000 and uses a polynomial of order 5. Animated versions of these figures that show the dynamics more vividly can be found at http://personal.lse.ac.uk/kleven/Downloads/MyPapers/WorkingPapers/best-kleven_landnotches_april2013_videos.pdf

Figure 8: Dynamics of Bunching Around the End of Stamp Duty Holiday



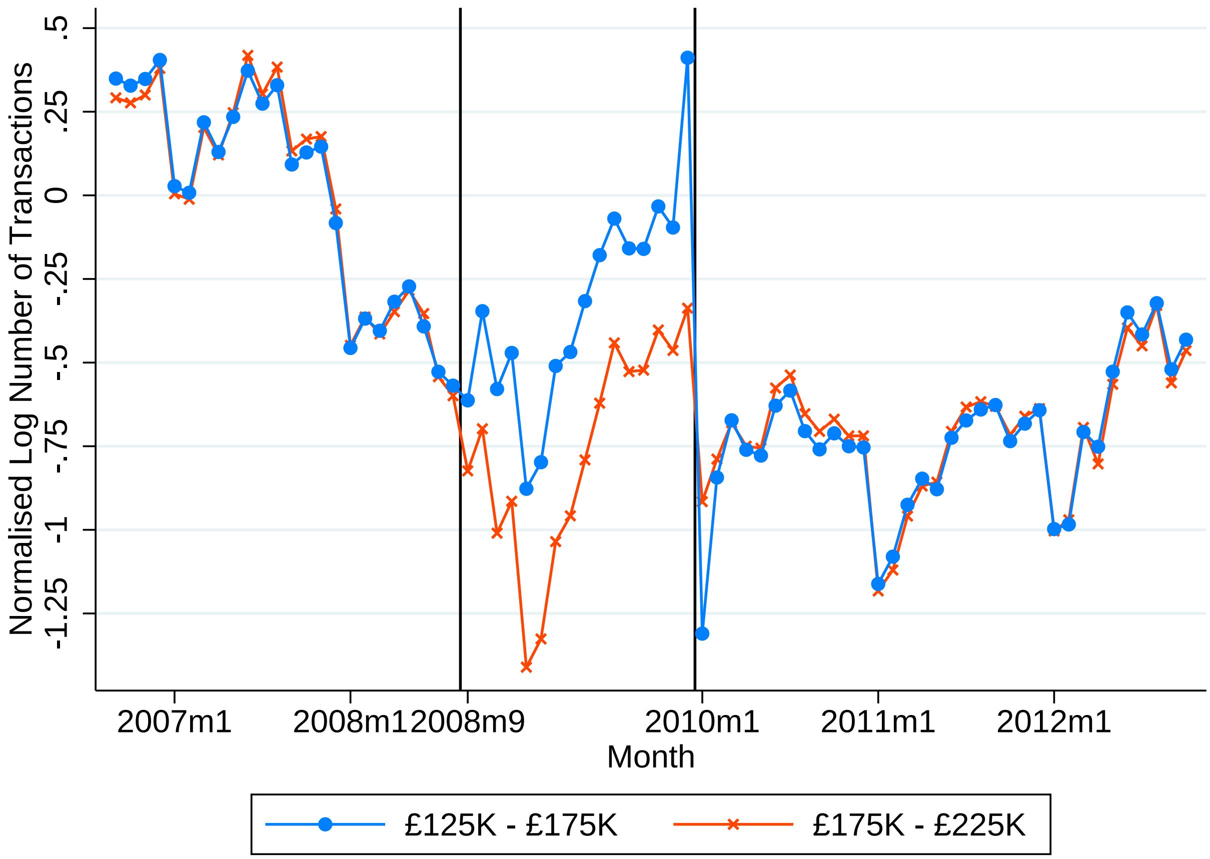
Notes: The figure shows the observed density of property transactions (blue dots) and our estimated counterfactual density (red line) in the region £75,000 – £225,000 separately for each month. On 1 January 2010, the bottom notch was moved back from £175,000 to £125,000 as announced previously. The estimation of the counterfactual is as described in section 4.1 and in the notes to figures 4 & 5. The estimation excludes data in the regions £115,000 – 140,000 and £170,000 – £190,000 and uses a polynomial of order 5. Animated versions of these figures that show the dynamics more vividly can be found at http://personal.lse.ac.uk/kleven/Downloads/MyPapers/WorkingPapers/best-kleven_landnotches_april2013_videos.pdf

Figure 9: Bunching Estimates Over Time



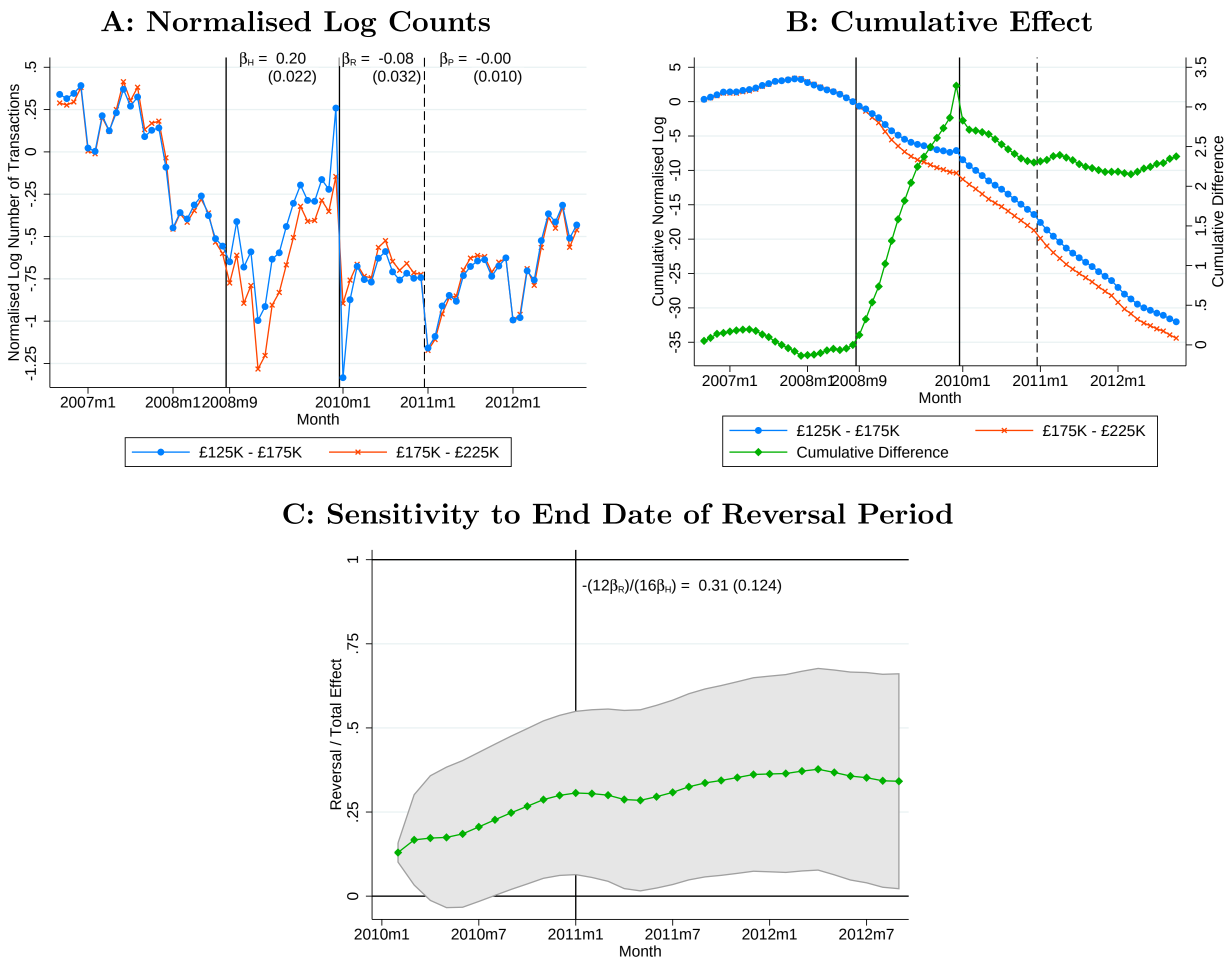
Notes: The figure shows our estimates of $b\left(\bar{h}_v\right)$, the bunching mass just below $\bar{h}_v$ scaled by the counterfactual frequency at $\bar{h}_v$, by month from January 2007 to February 2011 and for two values of $\bar{h}_v$, £125,000 (blue circles) and £175,000 (orange crosses). The first vertical line is at September 2008 when the stamp duty holiday was unexpectedly announced, moving the notch from £125,000 to £175,000. The dashed vertical line is at December 2008 to represent the observation that house transactions take up to 90 days to conclude, and so some inertia in the bunching responses is to be expected. The second vertical line is at December 2009 when the stamp duty holiday came to an end as anticipated, and the notch was moved from £175,000 back down to £125,000.

Figure 10: Effects of the Stamp Duty Holiday Stimulus: Naive Diff in Diff



Notes: The figure shows how the level of housing market activity changed over time in the price range affected by the stamp duty holiday (£125,000 - £175,000) and the neighbouring price range £175,000 - £225,000. The figure shows the normalised log monthly number of transactions defined as the log of the number of transactions in that month minus the average of the log of the number of transactions in the 24 months leading up to the start date of the Stamp Duty Holiday (September 2006 - August 2008).

Figure 11: Effects of the Stamp Duty Holiday Stimulus: Adjusting for Bunching



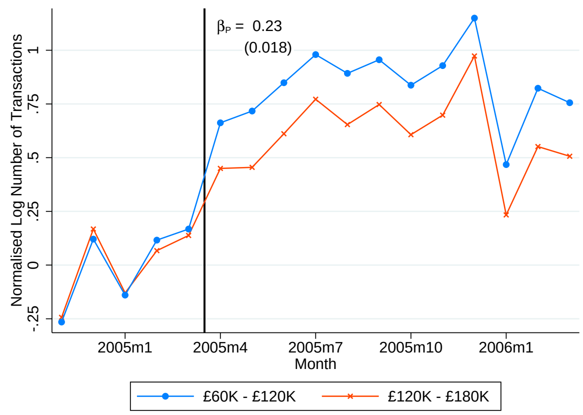
Notes: The figure shows the effect of the stamp duty holiday stimulus on housing market activity using the price range £125,000 - £175,000 as the treated price range and £175,000 - £225,000 as the control price range. However, all counts are adjusted for price manipulation using bunching estimates by moving excess transactions at £125,000 to prices between £125,000 and £150,000 and moving excess transactions at £175,000 to prices between £175,000 and £200,000. Panel A shows the normalised log monthly number of transactions defined as the log of the number of transactions in that month minus the average of the log of the number of transactions in the 24 months leading up to the start date of the Stamp Duty Holiday (September 2006 - August 2008). Superimposed on that are our estimates of β_H, β_R and β_P from the regression

$$\begin{aligned} n_{it} &= \alpha_0 Pre_t + \alpha_H Hol_t + \alpha_R Rev_t + \alpha_P Post_t + \alpha_T Treated_i \\ &\quad + \beta_H Hol_t \times Treated_i + \beta_R Rev_t \times Treated_i + \beta_P Post_t \times Treated_i + \nu_{it} \end{aligned}$$

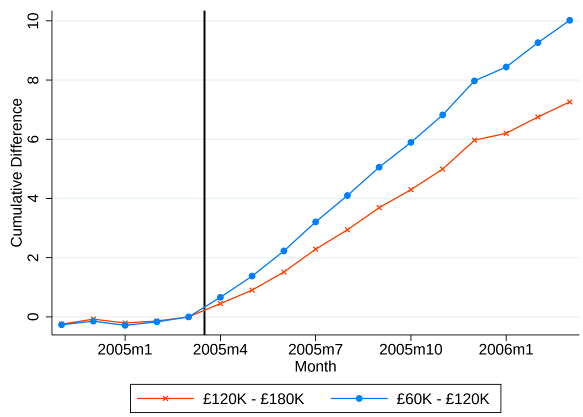
where n_{it} is the log of the monthly number of transactions Pre_t is a dummy for the pre-period September 2006–August 2008 inclusive, Hol_t is a dummy for the stamp duty holiday period September 2008–December 2009, Rev_t is a dummy for the post-holiday reversal period January–December 2010 inclusive, and $Post_t$ is a dummy for the later months January 2011–October 2012 inclusive. $Treated_i$ is a dummy for the treated price range and finally ε_{it} is an error term. Panel B shows the cumulative sum of the normalised log counts in panel A (blue dots and orange crosses) as well as the cumulative sum of the differences between the treatment and control groups (green diamonds). Panel C shows how the proportion of the total effect of the stamp duty holiday that is undone by reversal after the end of the holiday changes as we use different months as the first month after the effect is gone. Specifically, it shows $(\Sigma_t Rev_t \times \beta_R) / (16\beta_H)$ as the end date of the period used to define Rev_t changes. The vertical line is at our preferred choice for the first month of $Post_t$, January 2011, which gives an estimate of the proportion of the total effect undone by reversal of 0.31 (0.124).

Figure 12: Effects of the Permanent Reform: Adjusting for Bunching

A: Normalised Log Counts



B: Cumulative Effect



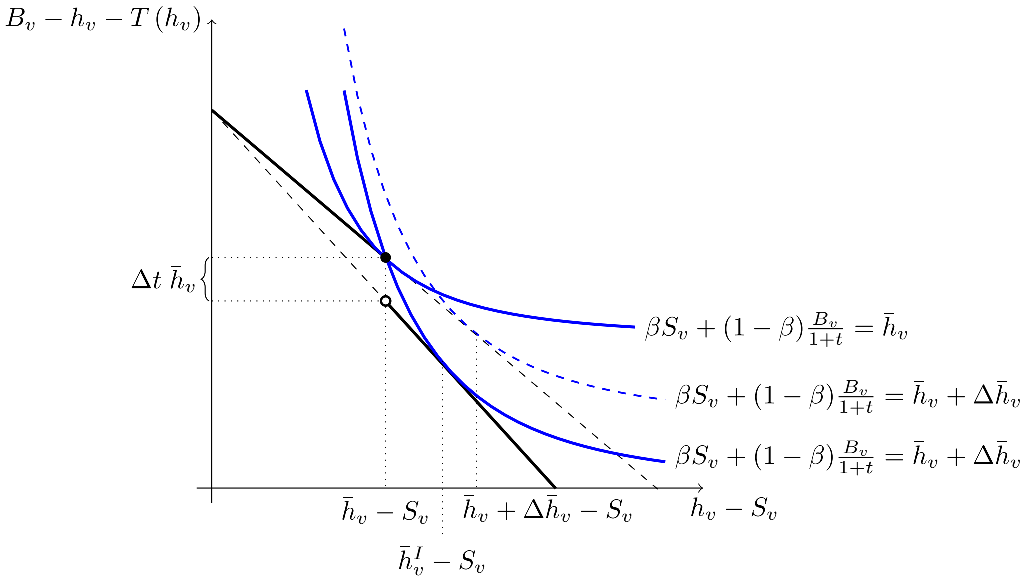
Notes: The figure shows the effect of the permanent tax cut of March 2005 when the bottom notch was moved from £60,000 to £120,000 on housing market activity using the price range £60,000 - £120,000 as the treated price range and £120,000 - £180,000 as the control price range. However, all counts are adjusted for price manipulation using bunching estimates by moving excess transactions at £60,000 to prices between £60,000 and £85,000 and moving excess transactions at £120,000 to prices between £120,000 and £145,000. Panel A shows the normalised log monthly number of transactions defined as the log of the number of transactions in that month minus the average of the log of the number of transactions in the 5 months we have data for leading up to the date of the reform (November 2004 - March 2005). Superimposed on that is our estimates of β_P from the regression

$$n_{it} \quad = \quad \alpha_0 Pre_t + \alpha_P Post_t + \alpha_T Treated_i + \beta_P Post_t \times Treated_i + \nu_{it}$$

where n_{it} is the log of the monthly number of transactions Pre_t is a dummy for the pre-period November 2004–March 2005 inclusive, $Post_t$ is a dummy for the months after the reform April 2005–March 2006 inclusive. $Treated_i$ is a dummy for the treated price range and finally ε_{it} is an error term. Panel B shows the cumulative sum of the normalised log counts in panel A (blue dots and orange crosses).

A Online Appendix (Not Intended For Publication)

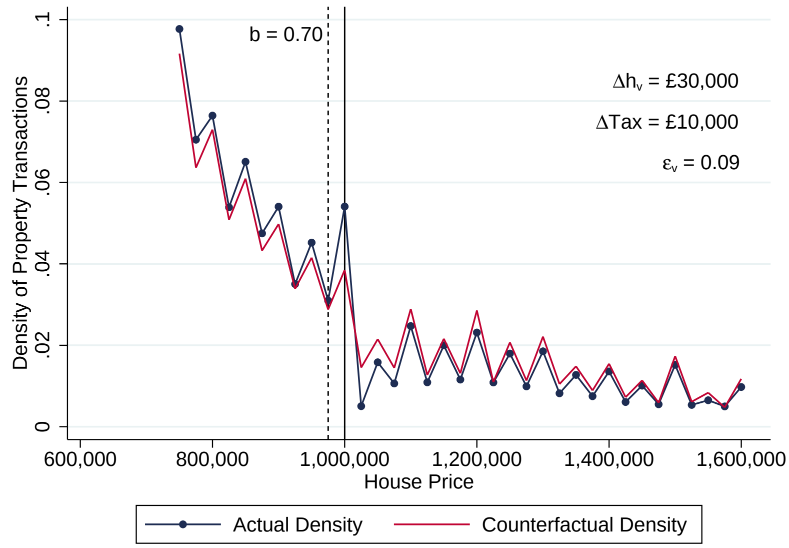
Figure A.1: Budget Set Diagram for Bargaining Model



Notes: The budget set diagram depicts the Nash product as in equation (11) and the budget set of feasible allocations under the notched tax schedule in the space of net of tax surpluses (i.e. $(B_v - h_v - T(h_v), h_v - S)$-space) and illustrates intensive responses among individuals with heterogeneous valuations $\{B_v, S_v\}$, but a specific bargaining power β. The notch creates bunching at the cutoff $\bar{h}_v$ by all individuals in a preference range $\beta S_v + (1-\beta)\frac{B_v}{1+t} \in [\bar{h}_v, \bar{h}_v + \Delta\bar{h}_v]$, who would have bargained prices on the segment $[\bar{h}_v, \bar{h}_v + \Delta\bar{h}_v]$ in the absence of the notch. The marginal bunching match is indifferent between the notch point $\bar{h}_v$ and the best interior location $\bar{h}_v^I$. No individual is willing to locate between $\bar{h}_v$ and $\bar{h}_v^I$, and hence this range is completely empty. This figure is the direct analog of panel A of figure 1, and shares all its qualitative features.

Figure A.2: Bunching and Holes Around the Highest Notches

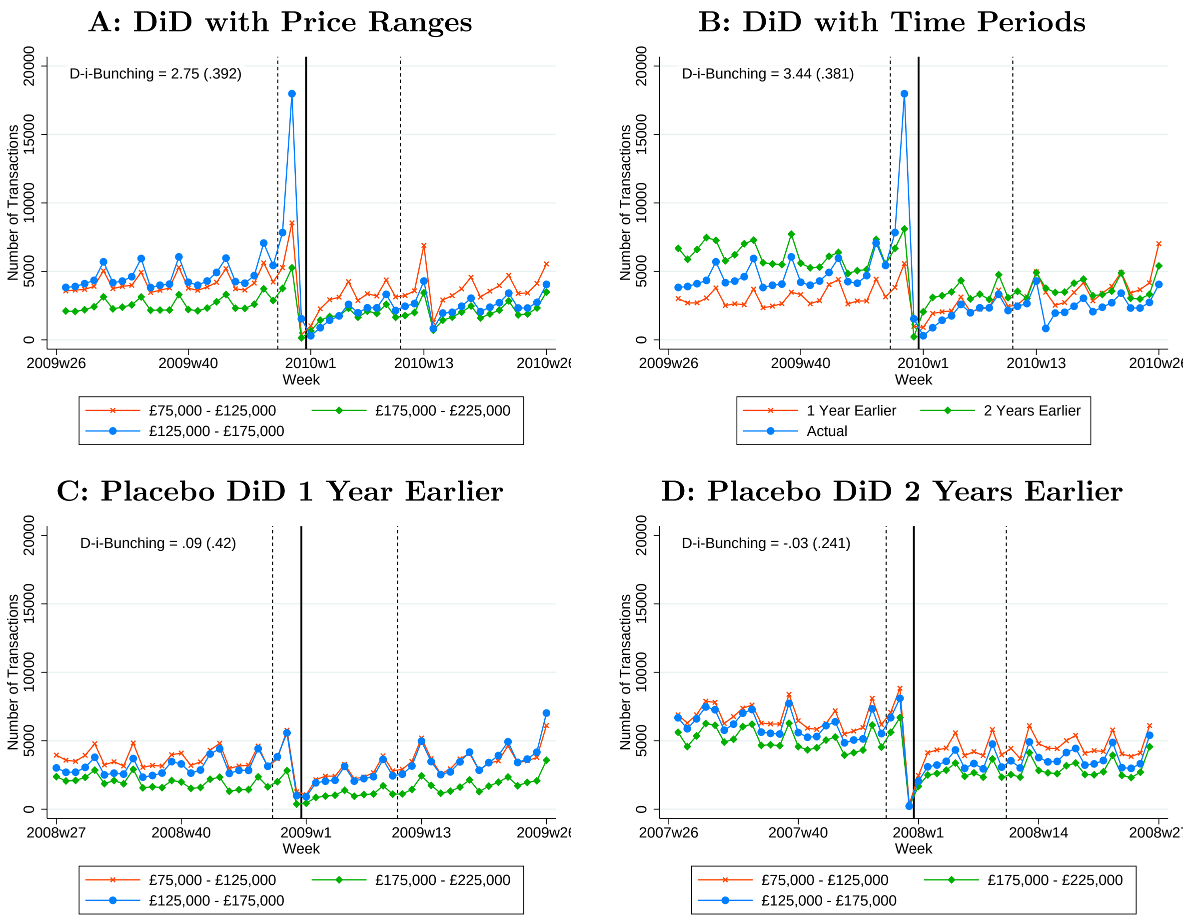
A: Notch at £1,000,000



B: Notch at £2,000,000

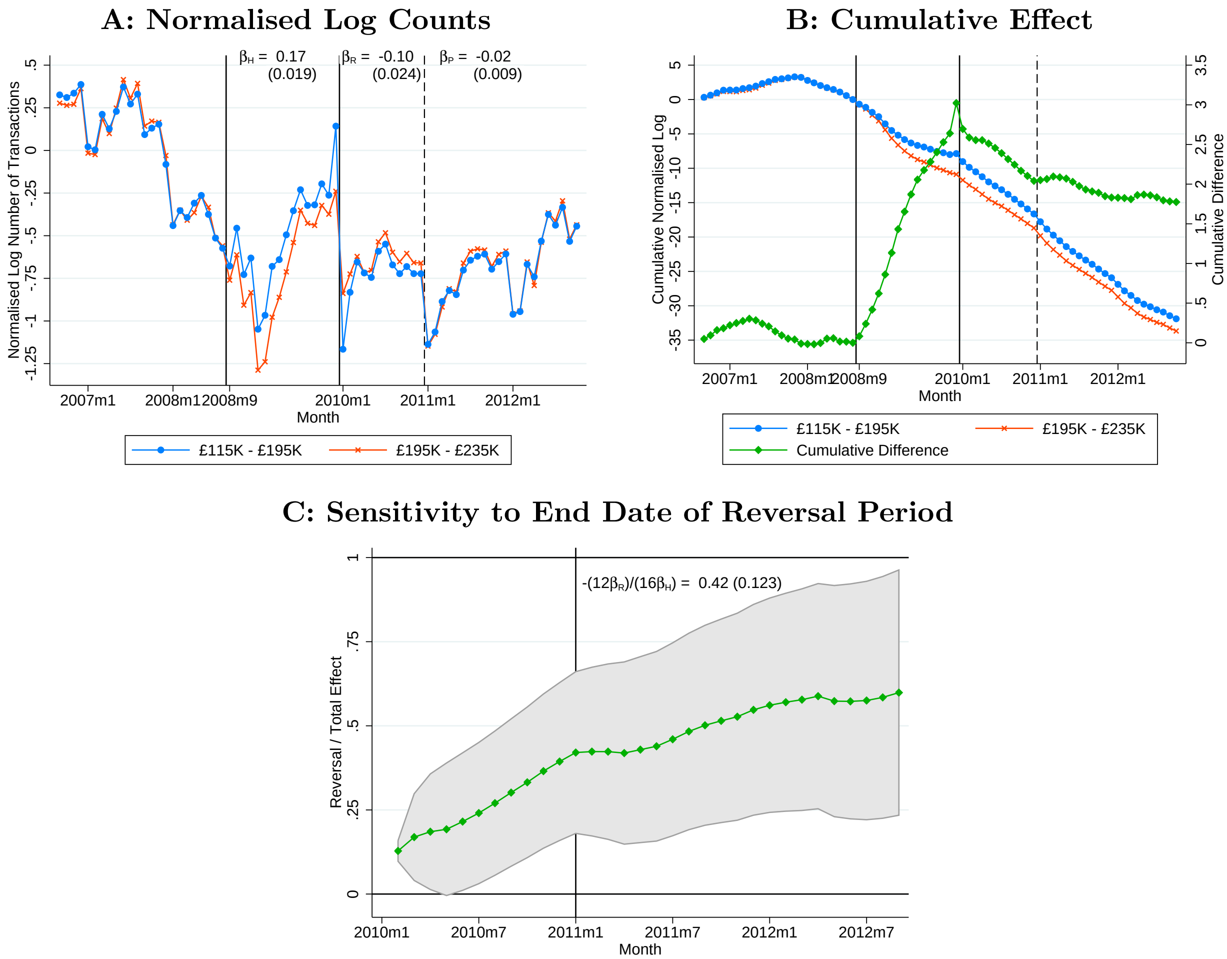
Notes: The figure shows the observed density of property transactions (blue dots) and the density of property transactions in the year leading up to the introduction of the notch (red line) around the notches for very high value properties. The vertical dashed lines denote the upper and lower bounds of the excluded region around the notch. The upper bound of the excluded region is chosen as the point where the observed density changes slope from positive to negative. Panel A shows the notch at £1,000,000 introduced on 6 April 2011 where the tax liability jumps by £10,000 (from 4% to 5% of the transaction price) with both densities aggregated up to bins £25,000 wide. Panel B shows the notch at £2,000,000 introduced on 22 March 2012 where the tax liability jumps by £40,000 (from 5% to 7% of the transaction price) with both densities are aggregated up to bins £50,000 wide. b is our estimate of the excess mass just below the notch scaled by the average counterfactual frequency in the excluded range and m is our estimate of the missing mass above the notch scaled by the average counterfactual frequency in the excluded range. $m - b$ is our estimate of the difference between the missing mass and the bunching mass. The figures also show the average house value change created by the notch, and the tax liability change at the notch.

Figure A.3: Time Notch



Notes: The figures show counts of the number of transactions in various weeks around the end of the stamp duty holiday on 31 December 2009. Panel A shows the number of transactions taking place between 2009w27 and 2010w26 in the treated price range £125,000 – £175,000 (blue circles) alongside the number of transactions in the price ranges £75,000 – £125,000 (orange crosses) and £175,000 – £225,000 (green diamonds). Panel B shows the number of transactions taking place in the treated price range (£125,000 – £175,000) in the year around the end of the stamp duty holiday, 2009w27 to 2010w26 (blue circles) as well as 1 year earlier (orange crosses) and 2 years earlier (green diamonds). Panel C shows the first placebo difference in differences exercise, depicting the same price ranges as in panel A, but using data from 1 year earlier. Similarly, panel D shows the second placebo difference in differences exercise, depicting the same price ranges as in panel A, but using data from 2 years earlier. The solid vertical line is placed at the end of the year (which at the end of 2009 is the end of the stamp duty holiday) and the dashed vertical lines demarcate the last 3 weeks of the year and the first 10 weeks of the year, which are the excluded range for the counterfactual estimates. The counterfactual is estimated as a 7th order polynomial, and includes fixed effects for the last week of each month (except December), when there is a visible spike in each month. We do not include a fixed effect in December because this month is clearly special due to the holiday season, featuring a spike in the penultimate week of the year and a lull in the last week of the year. This seasonality is captured by the bunching estimates in the control groups and the placebo exercises. Overlaid on each picture is the difference-in-bunching estimate corresponding to the choice of treatment (blue circles) and control groups (orange crosses and green diamonds) depicted in the picture. The DiD estimate is the difference between the bunching (normalised by the height of the counterfactual) in the treatment group and the average of the bunching in the two control groups.

Figure A.4: Effects of the Stamp Duty Holiday Stimulus: Diff in Diff With Wider Treatment Range



Notes: The figure shows the effect of the stamp duty holiday stimulus on housing market activity using the price range £115,000 - £195,000 as the treated price range and £195,000 - £235,000 as the control price range. Panel A shows the normalised log monthly number of transactions defined as the log of the number of transactions in that month minus the average of the log of the number of transactions in the 24 months leading up to the start date of the Stamp Duty Holiday (September 2006 - August 2008). Superimposed on that are our estimates of β_H, β_R and β_P from the regression

$$\begin{aligned} n_{it} &= \alpha_0 Pre_t + \alpha_H Hol_t + \alpha_R Rev_t + \alpha_P Post_t + \alpha_T Treated_i \\ &\quad + \beta_H Hol_t \times Treated_i + \beta_R Rev_t \times Treated_i + \beta_P Post_t \times Treated_i + \nu_{it} \end{aligned}$$

where n_{it} is the log of the monthly number of transactions Pre_t is a dummy for the pre-period September 2006–August 2008 inclusive, Hol_t is a dummy for the stamp duty holiday period September 2008–December 2009, Rev_t is a dummy for the post-holiday reversal period January–December 2010 inclusive, and $Post_t$ is a dummy for the later months January 2011–October 2012 inclusive. $Treated_i$ is a dummy for the treated price range and finally ε_{it} is an error term. Panel B shows the cumulative sum of the normalised log counts in panel A (blue dots and orange crosses) as well as the cumulative sum of the differences between the treatment and control groups (green diamonds). Panel C shows how the proportion of the total effect of the stamp duty holiday that is undone by reversal after the end of the holiday changes as we use different months as the first month after the effect is gone. Specifically, it shows $(\beta_R \Sigma_t Rev_t) / (16\beta_H)$ as the end date of the period used to define Rev_t changes. The vertical line is at our preferred choice for the first month of $Post_t$, January 2011, which gives an estimate of the proportion of the total effect undone by reversal of 0.42 (0.123).

Table A.1: Immediate Impact of Fiscal Stimulus on GDP

	Time Since Last Move		
	$<$ 1 Year	**$\geq$ 1 Year**	**$\geq$ 5 Years**
Panel A: Moving-Related Household Spending			
Repairs & Improvements	3,153	1,707	1,447
Furnishings	2,912	817	751
Appliances	153	87	100
Other Durables	426	434	436
Total Expenditure	6,644	3,043	2,734
Difference Movers - Stayers		3,600	3,909
Difference Movers - Stayers (% of house value)		1.57	1.70
Estate Agent Commissions (% of house value)		1.98	1.98
Other Commissions (% of house value)		1.24	1.24
Impact of Purchase on Expenditure: ϕ (% of house value)		4.79	4.92
Panel B: Immediate Impact of Policy on GDP			
Impact of Policy on GDP per £ of Tax Cut ($\beta_H \times \phi$) using $\beta_H = 0.20$		0.96	0.98
Impact of Policy on GDP per £ of Tax Cut ($\beta_H \times \phi$) using $\beta_H = 0.17$		0.81	0.84

Notes: The table shows estimates of the immediate impact of the stamp duty holiday stimulus on GDP. Using the UK Living Costs and Food Survey from 2011, the first 7 rows of panel A present estimates of moving-related spending on repairs, renovations, furnishings, appliances and other durables. To obtain only the moving-related part of these spending categories, we compare homeowners who moved within the last year (movers) to homeowners who moved more than 1 year ago or more than 5 years ago (non-movers). Row 6 shows our estimates of total moving-related spending on these categories in absolute numbers (£3,600-£3,909 depending on comparison group), while row 7 scales the estimates by the average house price of houses transacted in 2011, £230,000. Rows 8 and 9 show spending on commisions to agents, lawyers, etc. A 2011 survey by *Which? Magazine* estimates that estate agents' fees average 1.8% of the house price before VAT, or 1.98% with VAT (see http://www.which.co.uk/news/2011/03/estate-agents-fees-exposed-248666/). ReallyMoving (2012) estimates that other commissions and fees total £1,880 on average, and do not vary much with house value, so we scale this by the average value of houses bought in the range affected by the policy (£152,000). Combining rows 1-9, we reach our rough estimate of the effect of a house purchase on household spending (in % of the house price), which we denote by ϕ. This number is just below 5% independent of comparison group. In panel B we calculate the immediate impact of the policy on GDP (per £ of tax cut) as the moving-related spending triggered by the additional house transactions due to the policy. The total GDP effect is $\Delta GDP = \phi h_v^m \Delta n$ where h_v^m is the mean price of houses in the price range affected by the policy, and Δn is the number of additional house purchases induced by the policy. The foregone tax revenue is $\Delta Tax = \tau_0 h_v^m n_0$ where $\tau_0 = 1\%$ is the pre-stimulus tax rate, and n_0 is the counterfactual number of transactions. Combining these expressions, the effect of the policy is $\Delta GDP/\Delta Tax = \phi \Delta n/(\tau_0 n_0)$, where $\Delta n/n_0$ is our difference-in-differences estimate β_H in equation (17). The first row of panel B uses $\beta_H = 0.20$ as estimated in Figure 11, while the second row uses $\beta_H = 0.17$ as estimated in Figure A.4.