No taxation without capitalization*

Quantile treatment effects of land value tax reform on house prices

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Abstract

In this paper, I investigate the role of land value taxation on Danish house prices using quasi-experimental evidence from a 2007 reform, which merged 271 municipalities into 98 larger entities to improve administrative efficiency. By virtue of the merger, land value tax rates were substantially changed across the pre-merger municipalities. To this end, I web scrape the Danish aggregate house price portal `Boliga` for prices and individual characteristics of all Danish houses sold on the free market from 2000-2008. I use quantile regression to find a striking pattern: Land value taxes are capitalized into house prices, but the effect is stronger at the top of the market segment than it is at the bottom. For the 0.9th quantile, I find that a one per mille (0.1 percent) decrease (increase) to *effective* land value tax rates raised (lowered) house prices by around 5 percent. The effect was about half as pronounced at the 0.2nd quantile.

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*__Statement__: I hereby state that the data used in this paper is used for academic purposes only. The data contains personally identifiable information, so I cannot make it publicly available. All codes used in this paper are available here. The code for the web scraper used in this paper is based on work by Lassen and Høst (2022).

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Contents

1 Introduction

Land value taxation is said to be the "perfect tax" as it generates revenue without distorting economic decisions, such as conventional income taxes (Dye and England (2010)). For this reason, it is strongly advocated by prominent economists, including Piketty (2014) and Stiglitz (2015). Despite this, Denmark is one of only a few countries to use land value taxation. This makes empirical evidence of the role of land value taxation, in particular, to house prices and housing wealth, hard to come by. To this end, I exploit quasi-experimental evidence of changes to land value taxation resulting from the merger of Danish municipalities in the 2007 'Strukturreform'.[1] The aim of the reform was first and foremost to improve administrative efficiency and take a more uniform approach in managing local public finances. 206 out of the 271 pre-merger municipalities had less than 20,000 inhabitants, which made complex and expensive administrative tasks challenging to manage (KL (2009)).

Out of the 271 municipalities merged into 98 larger entities, land value taxes were raised in 132 pre-merger municipalities and lowered in 110 pre-merger municipalities (KL (2007)) by virtue of the reform. With this variation in mind, I seek to answer the following research question: *Do these changes to land taxes capitalize into house prices, and if so, is this capitalization heterogeneous across house prices?*

To investigate this proposition, I web scrape the Danish aggregate housing price portal `Boliga` to fetch information on all single-family homes sold on the free market between 2000 and 2008. I combine this with rich data on housing characteristics and geospatial data to identify how much each house experienced changes to *effective* property land taxes.

My results show a striking pattern: Quantile treatment effects of changes to property land taxes are substantially stronger at the top than it is at the bottom. For the 0.9th quantile, I find that a one per mille increase (decrease) to *effective* land tax rates lowered (raised) house prices by over 5 percent in the aftermath of the 2007 reform. For the 0.2nd quantile, the effect was about half.

This paper is structured as follows: Section 2 outlines the institutional setting surrounding the reform. Section 3 describes the data collection process along with descriptive statistics. I define my empirical strategy and results hereof in Section 4. In Section 5, I summarize and conclude.

[1] The Danish term for land value taxation is 'grundskyldspromille'.

1.1 Literature

My study adds to the relatively limited literature on land value taxation. First and foremost, I add to the evidence of capitalization of changes to land value taxation in a Danish context found in Høj et al. (2018), who investigate the same 2007 reform in Denmark as I do. Methodologically, my study differs from Høj et al. (2018) as I use quantile regression instead of standard OLS to investigate the (potentially) heterogeneous effects across house prices.

Elinder and Persson (2017) find evidence of limited capitalization of a (national) property tax reform in Sweden. Only in the 95th-98th percentile do they find capitalization effects. However, like me, the effect is stronger at the very top of the market segment.

Borge and Rattsø (2014) examine the relationship between property land taxes and housing prices in Norway between 1997-1999. As local governments can decide whether or not to impose property taxes in Norway, the authors resort to an instrumental variable approach to isolate the effect of differences in property taxation. They also find capitalization effects on house prices. This is not a concern for me, given that changes to property taxation were exogenously imposed on Danish house owners.

Oliviero and Scognamiglio (2019) investigate a 2012 reform to the Italian municipal tax system and its influence on house valuations. This reform came to life due to the resignation of the incumbent Italian government in 2011 in light of the debt crisis which faced Italy at this time. The technocratic government that took over introduced a municipal property tax to improve public finances. The authors exploit this sudden change to causally determine the effect on property values. Keep in mind that these valuations are based on both transaction data and surveys of local housing market conditions conducted among Italian real estate agents. They find that a one standard deviation increase to the municipal tax rates leads to a 2.7 percent decrease in property values. Keep in mind my data is entirely based on transactions, so my results may not be directly translatable.

2 Institutional setting

Since 2007, land taxes have been imposed by municipalities and is levied on the land value of the plot on which a property is built (Høj et al. (2018)). Before the reform in 2007, both counties and municipalities levied taxes on house owners. The counties collected a flat tax rate of up to 10 per mille (1 percent) of house land values. In addition, municipalities could collect land value taxes between 6 and 24 per mille of land valuations as per their public finance needs (Jepsen and Dietrich (2022)).

There were various catalysts for the reform. 206 out of the 271 pre-merger municipalities had less than 20,000 inhabitants. This made it difficult to manage complex and expensive administrative tasks, such as highly-specialized youth care, see Klitgaard (2017). This was also reflected in local public finance needs. As such, land value tax rates did vary considerably across Denmark prior to 2007, though at no point can you argue they did so for exogenous reasons. They may have been due to differences in, say, demographics. Thus, the identification of capitalization effects of land value taxation is challenging at best.

The outcome of the 2007 reform provided the quasi-experimental variation needed to identify potential capitalization effects. Counties were removed altogether, and 270 municipalities were merged into 98. Crucially, the 'new' geographical entities were given complete autonomy to set land value tax rates between 16 and 34 per mille of land valuation (Jepsen and Dietrich (2022)). Now, the 'heavy-lifting' of complex administrative tasks could be shared among fewer jurisdictions, meaning land value tax rates were changed 'exogenously' area-by-area in light of the reform.

Except for a few pre-merger municipalities, the reform essentially lowered the number of municipalities by merging them one-by-one into larger entities. However, a few pre-merger municipalities were first split up and then merged into new jurisdictional areas. I ignore these as they provide considerable complexity in assigning the correct changes to land taxes.

Naturally, the reform of 2007 did not come as a complete (exogenous) shock. For years, there had been ongoing debate to merge municipalities. The Venstre/Konservative government established a formal commission to investigate the need for administrative reform as early as 2002 (Internal Affairs (2004)). By the summer of 2004, it was public knowledge that land taxes were subject to change, and in the fall of 2006, the levels of the new property land taxes were established. Therefore, people likely shaped their expectations in response to this information.

Also relevant in the context of the 2007 reform, Denmark introduced a nominal "freeze" to property value taxation in 2002. This meant that taxes paid on the property's valuation have been nominally unchanged since 2002. Several high-ranking scholars, including those affiliated with the Danish Economic Council, have suggested that this has amplified the regional disparities in the Danish housing market (Svarer et al. (2016)).

To avoid confusion regarding different 'sets' of municipalities (before and after 2007), I refer to the geographical entities as 'areas' henceforth.

3 Data

Having set the scene in the previous section, I turn to describe my data in this section. First, I provide a few descriptive statistics and briefly go over how I have acquired the data. I focus only on single-family homes, as the land value tax is levied on a single owner rather than shared as is effectively the case for apartment owners. This makes the potential capitalization effect of changes to land value taxation for apartments considerably more complicated to identify.

3.1 Data collection

A summary of my data sources can be found in Table 1. My main data source is `Boliga`, which is a Danish aggregate house price portal. I specifically make use of their API by webscraping all single-family homes sold on the free market between 2000 and 2008. In total, I get 374,895 properties by doing this. This process is fairly straightforward given that I can make requests to the API fetching around 2,000 homes with unique IDs wrapped in a JSON file with each call. This gives me information on house size, address, price, size, number of rooms and, crucially, GPS coordinates of this specific address. I will come back to why this is important.

I supplement this data with information from the Danish Building and Dwelling Register ("BBR") of each home. This is also done via `Boliga`. The BBR has extremely detailed info on practically every housing characteristics, you can think of, and as a result has been heralded as one of the leading property valuation systems in the world (Almy (2014); Milan et al. (2016)). The property valuation takes into account three main characteristics: i) The building itself, such as number of rooms, bathrooms, garage etc, ii) The plot of land of which the building reside on and iii) Amenities and proximity to key infrastructure (Vurderingsstyrelsen (2023)). In conclusion, this data is arguably the best proxy for any differences in quality between individual houses. Please note here that this register relies on self-reported housing characteristics that affect the property assessments and so may contain errors, which I cannot account for.

In addition, I have acquired data on regional house price index from Statistics Denmark, table EJ55 and shapefiles of the 'old' Danish municipalities and regions from Dataforsyningen. Using the GPS coordinates from `Boliga`, I can link each house to the pre-merger municipalities with GeoPandas (Jordahl et al. (2020)), as this information is not readily available elsewhere. Finally, data of changes to the area/municipal land property land taxes are taken from KL (2007).

Because it is difficult to infer a causal interpretation of changes to the land tax rate itself, which only varies between municipalities, I take inspiration from Høj et al. (2018) and focus on *effective* land tax rates that varies across individual houses. Consider the following equation:

$$\Delta ELTR_{h,a} = \Delta LTR_a \frac{L_{h,a}}{V_{h,a}} \tag{1}$$

For any property h in area a, equation (1) states that the difference of the effective land tax rate following the 2007 reform is the fraction of the total property value paid in land tax in area a. If land taxes are capitalized into house prices, it must be that house prices are inversely related to changes to land taxes.

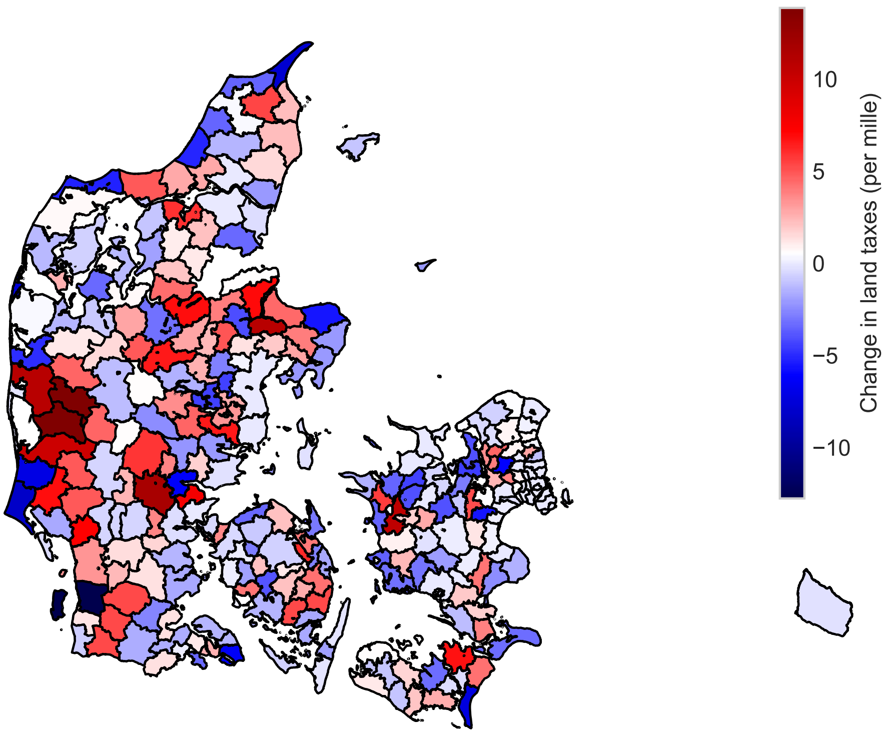
Table 1: Summary of data sources

Data source	Description
`Boliga`	House sale data, including price, GPS coordinates, and property evaluations from the Danish Buiding Register ("BBR").
`Statistics Denmark`	Regional house price index, Table EJ55 (2006=100).
`Dataforsyningen`	Shapefiles of pre-merger municipal borders.
`Kommunernes Landsforening`	Changes to land value taxes by pre-merger municipalities.

3.2 Descriptive statistics

I make a few descriptive plots to provide a visual representation of my data. A visual inspection of Figure 1 illustrates the national variation in changes to land taxes following the reform in 2007. I treat these changes as exogenous to identify a capitalization effect on house prices. Of 266 areas, 132 raised land taxes, another 110 lowered land taxes, while 24 left land taxes unchanged. I specifically turn my attention to the areas that experienced changes to land taxes, as I believe these will provide ample variation when identifying effects.

Figure 1: Changes to land value tax rates by pre-merger municipalities



Source: KL (2007) with geospatial data from Dataforsyningen (2023). A few areas have been intentionally left out from the map due to complexity in assigning the correct change to land taxes, see section 2 for more details.

Table 2 shows the two areas with the most significant changes to land taxes in percentage points per mille, with Ørbæk on the Island of Funen and Augustenborg in South Jutland raising taxes by 13.86 and lowering taxes by 12.76 percentage points per mille, respectively. Table 3 illustrates the considerable national variation in changes to effective land taxes in 2007. Overall, the average (nationwide) change to effective property land taxes is slightly positive at around 0.07 per mille points with a standard deviation of 0.84, which highlights how much this varies across houses. The most significant variation of effective land taxes is found in the areas that saw an increase, with an average change of 0.67 per mille points and a standard deviation of 0.73.

Table 2: Highest/lowest change to land taxes per mille points

	Area	Land tax change
Highest	Ørbæk	13.86
Lowest	Augustenborg	-12.76

Source: KL (2007)

Table 3: Average change to effective land taxes by area category

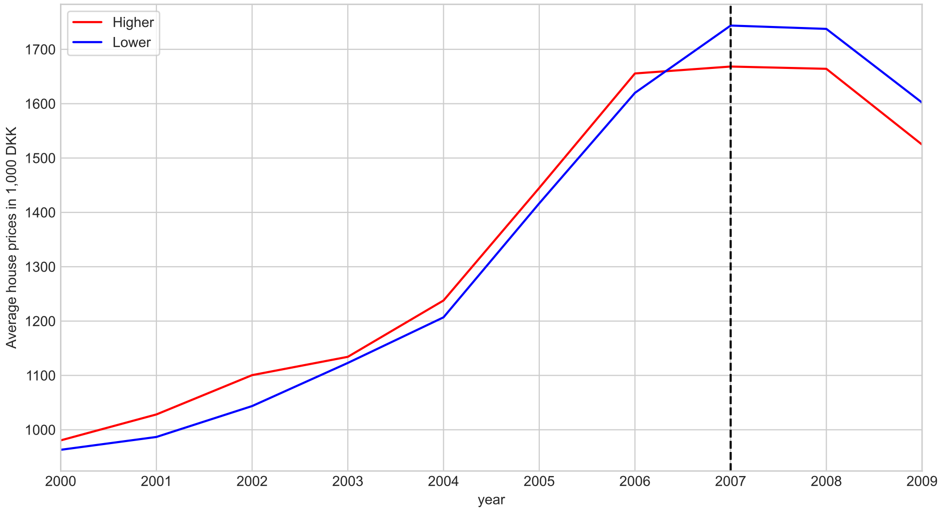
Category	Per mille points	Standard deviation
Raised land taxes	0.67	0.73
Lowered land taxes	-0.45	0.52
Average change	0.07	0.84

Source: KL (2007). This refers to houses sold after the reform was implemented.

Figure 2 in conjunction with Table 4 establishes the motivation for examining this particular reform. Graphically, it looks as if land tax changes do in fact capitalize into house prices. In 2003, well before the reform was implemented, prices were, on average 11,000 DKK higher in areas that experienced increasing land value taxes compared to those areas that later lowered taxes. When the reform was implemented in 2007, this price difference reversed. In 2007, houses sold in areas that raised land value taxation were, on average, 75,000 DKK cheaper than those sold in areas where taxes were decreased, an estimated difference-in-difference of 86,000 DKK.

This, at least on the surface, indicates a capitalization effect. There are a multitude of problems in drawing this conclusion. Are you simply buying larger/smaller houses between the two areas? Are there systematic differences in the 'quality' of homes bought after the reform? In the following section, I outline my empirical strategy to account for these potential issues.

Figure 2: Average single-family house prices, pre/post of the 2007 'Strukturreform'



Source: Own calculation with data from Boliga (2023). The lines are split between areas that raised (red) and lowered (blue) land taxes following the 2007 reform

Table 4: Average single-family prices pre/post of the 2007 'Strukturreform'

	2003	2007	Difference
Higher	1134.22	1668.35	534.13
Lower	1122.99	1743.78	620.80
Difference	11.23	-75.43	-86.67

Source: Boliga (2023). Prices are nominal and denoted in 1,000 DKK.

4 Empirical framework

Until now, I have shown indications of the capitalization effects of changes to land tax rates in the context of the 2007 reform. In this section, I outline my empirical strategy to causally determine whether these changes did in fact capitalize into house prices, and whether this effect is heterogenous across the distribution of house prices.

I first define a quantile difference-in-difference model with area- and year-fixed effects. For computational simplicity, I assume these fixed effects to affect quantiles *equally*. I then expand the model to include within-quantile fixed effects.

4.1 Estimation strategy

More often than not, economists are interested in a conditional mean of some outcome y conditional on several covariates $\mathbf{x}$, that is $E[y|\mathbf{x}]$. In this context, I seek to answer whether changes to land property taxation following the 2007 'Strukturreform' capitalized into house prices. This could be estimated using standard OLS methods using year and area fixed effects as is done by Høj et al. (2018). Assuming the estimates can be causally interpreted, they would only tell me of an average treatment effect and not whether the capitalization effect is heterogenous across the distribution of house prices.

To investigate this, consider the following quantile difference-in-difference regression inspired by Høj et al. (2018) as the starting point of my estimation strategy:

$$\ln P_{h,a,t}(\tau) = \beta_0(\tau) + \alpha_a + \gamma_t + \sum_{t=2005}^{2008} \phi_t(\tau)\Delta ELTR_{h,a} + \beta_1(\tau)\ln V_{01h,a} + \epsilon_{h,a,t}(\tau) \quad (2)$$

This specification is chosen in part for its computational simplicity. My outcome of interest is the logarithm of house prices P for house h in area a at time t, deflated by Statistics Denmark's regional house price index. I estimate my model for quantiles $\tau = 0.1, 0.2, ..., 0.9$.

My modeling choice implies that single-family homes in each price quantile, regardless of whether they were sold in areas that saw increases or decreases in land value tax rates, would be on the same price trend had there been no property tax reform. The nominal freeze to property taxes in 2002 could violate this assumption, see Section 2. For now, I will investigate the reform's effect under these assumptions. I will revisit and address the potential impact of the nominal freeze to property valuation taxes on my results later.

Year-dummies. Given the period between announcement and implementation, see section 2, I include yearly dummies interacted with the change in (effective) land taxes of the 2007 reform starting from 2005 up until 2008 to capture any gradual effect on prices. Recall that by mid-2004, it became public knowledge that property land taxes were subject to change. The period 2000-2004 thus serves as a pre-treatment period.

Coefficent(s) of interest. My main coefficients of interest is $\phi_{2007}(\tau)$. When I estimate year-interacted coefficients on the change to the effective land tax rate, I am effectively estimating a change in slope by year. This approach is analogous to what you would do in a "classic" OLS difference-in-difference model. However, in my case, I am estimating a change in slope by year as a function of τ quantiles of the entire distribution of my outcome variable, $\ln P_{h,a,t}$. The OLS-estimate is not a function of the distribution; it is simply a single estimate of an average effect.[2]

Fixed effects. I include area-specific fixed effect α_a to condition on any unobserved area-specific time-invariant confounders, while the year fixed effects γ_t controls for, say, any unobservable shocks specific to that year. The computational simplicity comes from my "two-step" procedure suggested by Canay (2011): I first estimate an OLS model with fixed effects by demeaning my dataset by area and year. I can then isolate the fixed effects and include these in a quantile regression model. The process implies that the fixed effects affect quantiles *equally*. The process is described in more detail in Appendix A.1.1.[3]

House quality. Further, I control for the logarithm of the public property assessment from the BBR dataset for house h in 2001 to capture any 'pure' difference in the quality of each house ($\ln V_{01,h,a}$). This is the last year before the nominal freeze to property valuation taxes, see Section 2. Note that this assumes the quality of houses and infrastructure is constant between 2001 and 2007.

Standard errors. As my "true" variation in the data is between houses, I follow Leth-Pedersen and Maire (2022) and cluster the standard errors on the individual house level ("robust" standard errors).

4.1.1 Results (I): Indications of heterogeneous effects?

Figure 3 show the results of the model specified in equation (2). A clear pattern emerges:

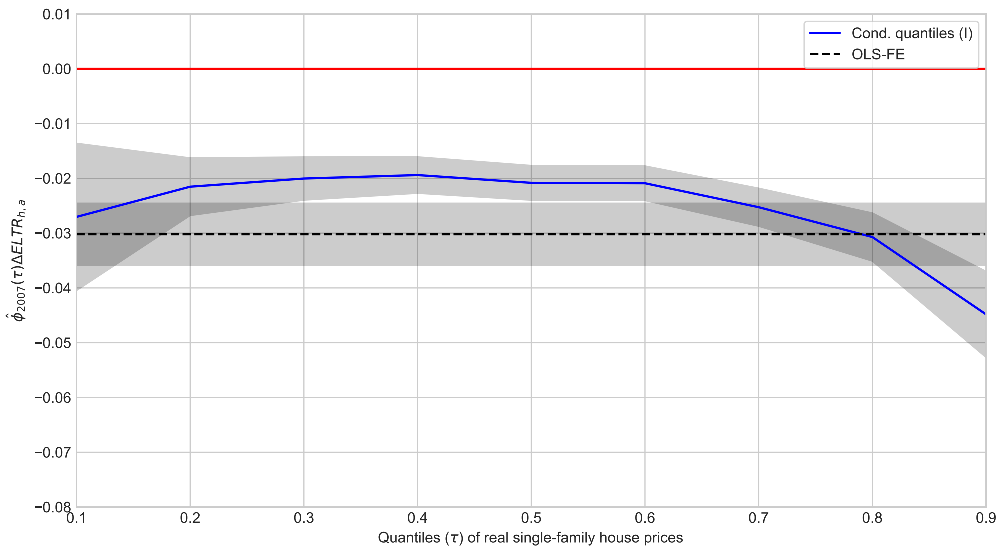
First, the treatment effect of changes to effective land taxes in 2007 is quite different across τ quantiles of house prices ($\phi_{2007}(\tau)$). At the $\tau = 0.2$ quantile, a one per mille (0.1 percent) increase to the effective land value tax rate decreased house prices by around 2 percent. At the $\tau = 0.9$ quantile, the capitalization effect is about double that found at the $\tau = 0.2$ quantile.

[2]For a more detailed understanding of the key definitions underlying the quantile regression model, I refer to Appendix A.1 where I outline key definitions that underpins a quantile regression model. I refer to Definition A.3 in this context.

[3]Canay (2011) calls these fixed effects 'location-shifters'. In my context, I find it more intuitive to think of them as affecting quantiles of house prices *equally*. More details can be found in his paper, but Canay essentially shows the consistency of a quantile regression estimator for a data-generating process on the functional form found in equation (2).

Second, Table 6 in Appendix A also indicates a gradual effect on prices, with year-coefficients decreasing over time in line with how the reform was communicated and implemented. I have included an OLS-estimate in precisely the same specification found in equation (2), except that I now model a conditional mean. This specification mimics the one found in Høj et al. (2018).

Figure 3: Quantile treatment effects of land tax reform on house prices



Note: Estimates from the model in equation (2) of the effect the 2007 'Strukturreform' ($\phi_{2007}(\tau)$) in quantiles of real house prices with 95 percent confidence bands. Standard errors are clustered at the individual house level ("robust" standard errors).

4.2 Extension

With the results found in Figure 3 in mind, I return to the relatively strong assumption on which they rely: i) that the area- and year-fixed effects affect quantiles equally and ii) that the pre-treatment years 2000-2004 for each quantile $\tau = 0.1, 0.2, ..., 0.9$ follow a parallel pre-trend.

First, to relax the assumption of the 'location-shifter' fixed effects, I rely on results by Machado and Silva (2019). In their paper, they derive a quantile regression estimator that allows for within-quantile fixed effects.[4] In the context of my paper, this means that I allow the unobserved fixed effects to differ across the entire distribution of house prices, which I would argue is a more favorable modeling choice than the 'simple' approach outlined by Canay (2011).

Second, my assumption of parallel pre-trends implicitly means that I am restricting $q \times T$ parameters, with $q = 9$ quantile estimates in $T = 5$ pre-trend periods (2000-2004), to be equal to zero. In the difference-in-difference econometric literature, it has recently been recommended to include a (linear) trend difference, see Bilinski and Hatfield (2018).

In light of this, I expand the model outlined in equation (2) to include within-quantiles fixed effects and a full set of year dummies interacted with changes to effective land tax rates starting from 2000 up until 2008, but restrict $\phi_{2004}(\tau) = 0$:

$$\ln P_{h,a,t}(\tau) = \beta_0(\tau) + \alpha_a(\tau) + \gamma_t(\tau) + \sum_{t=2000}^{2008} \phi_t(\tau)\Delta ELTR_{h,a} + \beta_1(\tau)\ln V_{01h,a} + \epsilon_{h,a,t}(\tau) \quad (3)$$

By doing this, I am allowing for a potential linear trend difference, which I suspect there may be at the higher quantiles of the house price distribution in light of the nominal property tax freeze in 2002.

4.2.1 Results (II): Evidence of heterogenous effects?

First, one notices from Table 5 that the pre-reform estimates in 2000-2003 are for the most part statistically insignificant. A few of the higher quantile estimates are statistically significant at conventional levels, though generally of small magnitude. This may be due to the nominal freeze in 2001, though I refrain from giving a definitive inter-

[4]See Machado and Silva (2019) for derivations. Essentially, they show the consistency of a quantile regression estimator for a data-generating process on the functional form found in equation (3).

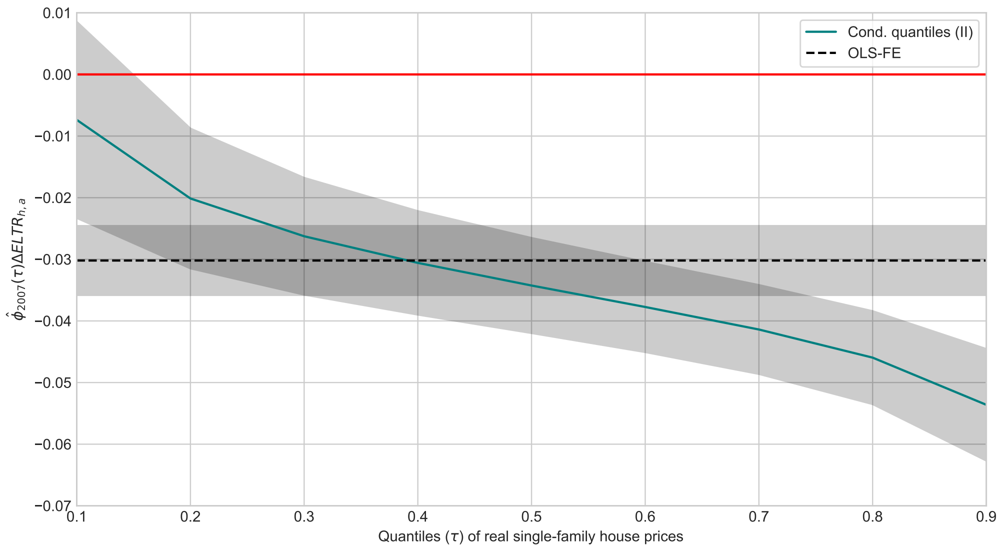
pretation. To see the complete set of quantile year-coefficients, I refer to Figure 6 in Appendix A.3.

Figure 4 in conjunction with Table 5 show the main results of this paper. These results are from the model specified in equation (3).

The heterogeneous effects of changes to land value taxation in 2007 have become much more pronounced than indicated in the prior model specification. At the $\tau = 0.2$ quantile, a one per mille increase (decrease) to effective land value tax rates reduced (increased) house prices by around 2 percent. At the $\tau = 0.9$ quantile, the change more than doubled to over 5 percent decrease (increase) to house prices.

In addition, the increasing year-coefficients from 2005-2007 indicate a gradual effect on prices in line with how the reform was communicated and implemented. Given the extraordinary circumstances surrounding the financial crisis and how this likely has impacted house prices differently, I refrain from giving the 2008-year coefficient a causal interpretation.

Figure 4: Quantile treatment effects of land tax reform on house prices



Note: Estimates from the model in equation (3) of the effect the 2007 'Strukturreform' ($\phi_{2007}(\tau)$) in quantiles of real house prices with 95 percent confidence bands. Standard errors are clustered at the individual house level ("robust" standard errors).

Table 5: Quantile treatment effects of changes to land tax rates

	Quantile regressions (II)			
	20%	50%	80%	OLS-FE
	(1)	(2)	(3)	(4)
Intercept	4.833***	4.857***	4.877***	-4.834***
	(0.030)	(0.047)	(0.045)	(0.020)
$\ln V_{01}$	0.666***	0.681***	0.694***	0.680***
	(0.005)	(0.003)	(0.003)	(0.001)
$2000\Delta ELTR$	-0.007	-0.007**	-0.008**	-0.008**
	(0.006)	(0.004)	(0.003)	(0.006)
$2001\Delta ELTR$	0.002	-0.003	-0.008***	-0.003
	(0.004)	(0.003)	(0.003)	(0.003)
$2002\Delta ELTR$	0.003	0.001	0.000	0.001
	(0.006)	(0.004)	(0.004)	(0.003)
$2003\Delta ELTR$	0.003	-0.006*	-0.013***	-0.005
	(0.005)	(0.003)	(0.003)	(0.003)
$2005\Delta ELTR$	-0.004	-0.018***	-0.030***	-0.017***
	(0.005)	(0.004)	(0.003)	(0.003)
$2006\Delta ELTR$	-0.019***	-0.029***	-0.037***	-0.028***
	(0.005)	(0.004)	(0.003)	(0.003)
$2007\Delta ELTR$	-0.020***	-0.034***	-0.046***	-0.033***
	(0.006)	(0.004)	(0.004)	(0.003)
$2008\Delta ELTR$	-0.005	-0.020***	-0.031***	-0.018***
	(0.007)	(0.004)	(0.004)	(0.004)
Observations	374,895	374,895	374,895	374,895

Note: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. Standard errors are clustered at the individual house level ("robust" standard errors). Estimates are from the model specified in equation (3).

4.3 Robustness checks

So far, I have argued that changes to land value taxation in 2007 had heterogeneous effects across the distribution of house prices. It could be inferred that the impact of the changes to effective land tax rates may be partially absorbed by differences in the quality of the municipal services and differences hereof following the reform. Consider the fact that if a municipality with low-quality services and low land value taxes were to be merged with a municipality with high-quality services and high land value taxes, chances are that it would experience an increase to both services and tax rates. This would theoretically have opposite effects on house prices.

Unfortunately, I do not have access to such temporal geographical data. Alternatively, I follow Høj et al. (2018) and include *income* tax changes following the 2007 reform. Naturally, this relies on the assumption that income taxes are a good proxy for services offered by the municipality. Since municipalities in Danish are required to run a balanced budget, higher tax revenues imply better services, ceteris paribus.

The exact model is specified in equation (6) in Appendix A.3. Figure 7 show all year-coefficients from this quantile regression. Quantile estimates of the 2007 reform ($\phi_{2007}(\tau)$) remain remarkably similar compared to my preferred within-quantile fixed effects model in equation (3), suggesting that changes to the quality of municipal services do not confound my results outlined above.

5 Conclusion

In this paper, I investigate the impact of changes to land value tax rates on house prices following a 2007 reform of Danish municipalities. To do this, I use a unique dataset containing all single-family homes sold on the free market in Denmark between 2000-2008, enriched with detailed housing characteristics. I webscrape this from `Boliga`.

The 2007 reform merged 271 municipalities into 98 to, first and foremost, improve administrative efficiency. This also implied exogenous changes to land value tax rates, given the more uniform approach to managing local public finances. Of the 271 pre-merger municipalities, 132 experienced an increase in land value tax rates, while 110 experienced a decrease. This reform did not come as a complete shock to the Danish population. By the summer of 2004, it was public knowledge that property land taxes were subject to change. It is therefore likely that people shaped their expectations in response to this.

With inspiration from Høj et al. (2018), I model the potentially gradual price effect of the 2007 reform in a quantile regression setting. Specifically, I define a quantile regression model that allows for within-quantile area- and year-fixed effects. By doing this, I am allowing unobserved fixed effects to vary across the distribution of house prices, which I argue is the most favorable modeling choice.

The extended quantile regression model results clearly show the capitalization effect into house prices. At the $\tau = 0.9$th quantile, I find that a 1 per mille (0.1 percent) increase (decrease) to effective land value taxes lowered (raised) house prices by around 5 percent. At the 0.2nd quantile, the effect was about half.

My results suggest that land value taxation can have redistributive effects on house equity. These results are also likely to have broader policy implications. In a strictly Danish setting, the nominal stop to property value taxation in 2002 has created relatively large regional disparities in house equity, as suggested by prominent scholars. Whether this is politically feasible is an exciting aspect to shed further light on, though this goes beyond the scope of this paper.

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A Appendix

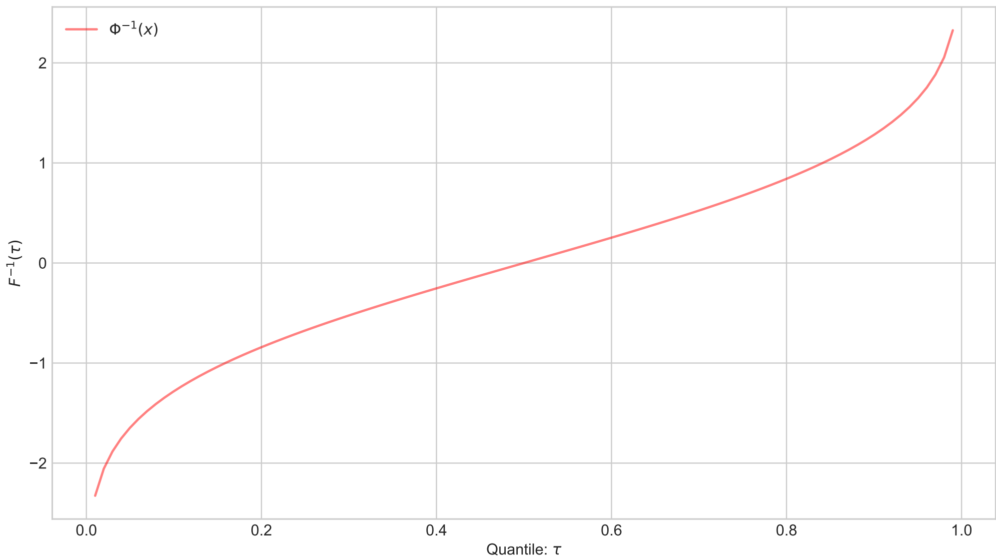
A.1 The quantile regression model

Suppose we have some continuous outcome y, which 'true' data-generating process is a function of some underlying covariates $\mathbf{x}$.[5] We may be interested in estimating the conditional mean, $E[y|\mathbf{x}]$. For that, we can apply ordinary least squares. However, we may also be interested in examining potentially heterogenous effects across the distribution of y, that is τ'th quantile of y. Define a quantile τ as:

Definition A.1 *The τ'th quantile $(\tau \in (0;1))$ of y is μ_τ such that*
$\tau = \Pr(y \leq \mu_\tau) \equiv F_y(\mu_\tau)$.
Hence
$\mu_\tau = F_y^{-1}(\tau)$.

For simplicity, let us assume $\mu_\tau = F_y^{-1}(\cdot) = \Phi^{-1}(\cdot)$, or the inverse of normal distribution CDF:

Figure 5: Cumulative distributive function (CDF), μ_τ



In more general terms, we may denote the quantile regression model as:

Definition A.2 $y_i = \mathbf{x}_i \boldsymbol{\beta}(\tau_i)$

[5] The following section builds on Cameron and Trivedi (2005) & Munk-Nielsen (2022)

Such that the k-parameter estimates can be interpreted as a function of the inverse CDF, $F^{-1}(\tau)$.

I skip the derivations of the quantile regression estimator (see Cameron and Trivedi (2005)). Instead, I highlight how x_{ik} affects conditional quantiles. One can show that this is in fact linear:

Definition A.3 $\frac{\partial \mu_\tau(\mathbf{x}_i, \boldsymbol{\beta}_\tau)}{\partial x_{ik}} = \beta_{\tau k}$

This definition is crucial to my analysis of potentially heterogenous capitalization effects. The year-interacted coefficients on the change to effective land tax rate measure the change in slope by year. This is what you would do in a "classic" difference-in-difference OLS-model.

A.1.1 The simple estimator by Canay (2011)

The two-step estimator for $\beta(\tau)$ of Canay (2011) can be defined as follows. For notational simplicity, suppose we have a panel of observed variables (Y_{it}, X_{it}) for $i = 1, ..., N$ and $t = 1, ..., T$.[6] The underlying 'true' data-generating process is on the functional form of conditional quantiles:

$$Y_{it} = X_{it}'\theta(\tau) + \alpha_i + e_{i,t}(\tau), \quad Q_{e_{it}(\tau)}(\tau \mid X_i, \alpha_i) = 0 \tag{4}$$

Here, we may note that the individual (fixed) effects are τ-independent. Let the fixed effects be equal to:

$$\hat{\alpha}_i = \bar{Y}_i - \hat{\theta}_\mu' \bar{X}_i \tag{5}$$

where $\bar{Y}_i = T^{-1}\sum_{t=1}^{T} Y_{it}, \bar{X}_i = T^{-1}\sum_{t=1}^{T} X_{it}$, and $\hat{\theta}_\mu$ is the standard fixed effect estimator, i.e.,

$$\hat{\theta}_\mu = \left(\sum_{i=1}^{N}\sum_{t=1}^{T} \ddot{X}_{it}\ddot{X}_{it}'\right)^{-1} \left(\sum_{i=1}^{N}\sum_{t=1}^{T} \ddot{X}_{it}\ddot{Y}_{it}\right),$$

where $\ddot{X}_{it} = X_{it} - \bar{X}_i$ and $\ddot{Y}_{it} = X_{it} - \bar{Y}_i$ are the within-transformed regressors and dependent variables. As such, we first estimate the model using OLS using the

[6]I follow the notation found in Chen and Huo (2021), when they 'revisit' the Canay-estimator in Section 2 in their paper.

demeaning approach. We then 'isolate' the fixed effects, which is then removed from outcome Y_{it}. Finally, in the second step, $\theta(\tau)$ is simply estimated by:

$$\tilde{\theta}(\tau) = \arg\min_{\theta} \sum_{i=1}^{N} \sum_{t=1}^{T} \rho_\tau \left(\tilde{Y}_{it} - \theta' X_{it} \right).$$

Where $\tilde{Y}_{it} = Y_{it} - \hat{\alpha}_i$.

A.2 Additional tables

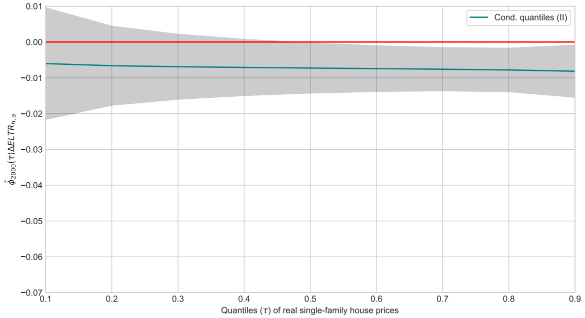
Table 6: Quantile treatment effects of land tax reform on house prices

	Quantile regressions (I)			
	20% (1)	50% (2)	80% (3)	OLS-FE (4)
Intercept	-2.319***	-1.182***	-0.148***	-4.834***
	(0.018)	(0.010)	(0.016)	(0.020)
$\ln V_{01}$	0.837***	0.769***	0.708***	0.680***
	(0.001)	(0.001)	(0.001)	(0.001)
$2005\Delta ELTR$	-0.003	-0.008***	-0.013***	-0.014***
	(0.002)	(0.002)	(0.002)	(0.003)
$2006\Delta ELTR$	-0.021***	-0.019***	-0.028***	-0.025***
	(0.003)	(0.002)	(0.002)	(0.003)
$2007\Delta ELTR$	-0.022***	-0.021***	-0.031***	-0.030***
	(0.003)	(0.002)	(0.002)	(0.003)
$2008\Delta ELTR$	-0.015***	-0.016***	-0.020***	-0.015***
	(0.003)	(0.002)	(0.003)	(0.003)
Observations	374,895	374,895	374,895	374,895

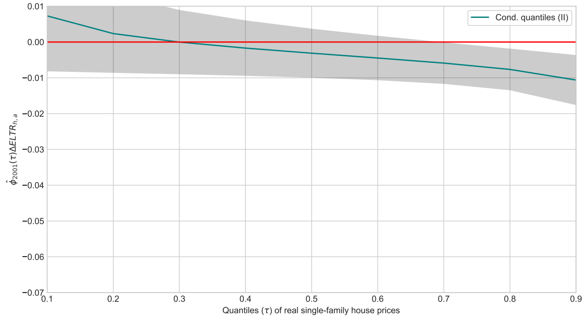
Note: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. Standard errors are clustered at the individual house level ("robust" standard errors). Estimates are from the model specified in equation (2).

A.3 Quantile year-coefficients

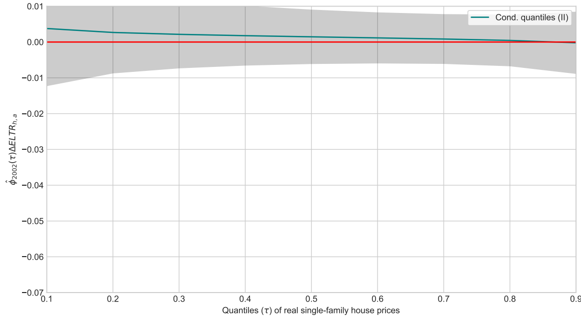
Figure 6: Quantile treatment effects, within-quantile-fixed effects



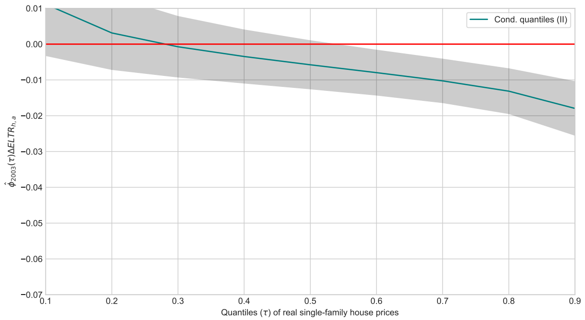
(a) 2000



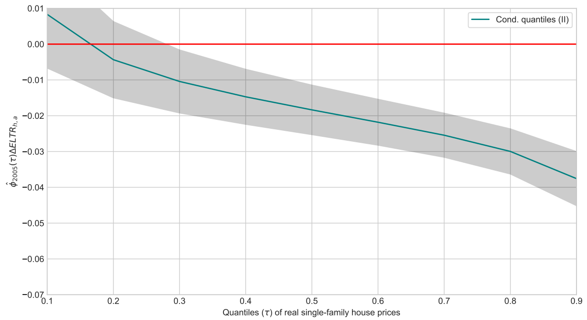
(b) 2001



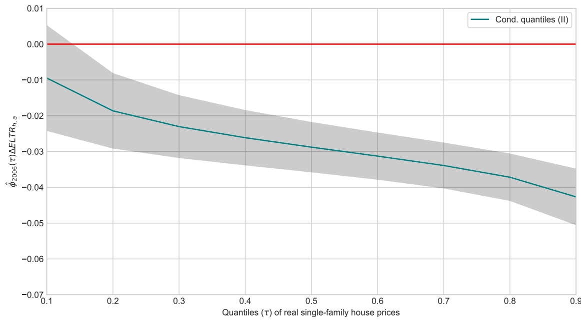
(c) 2002



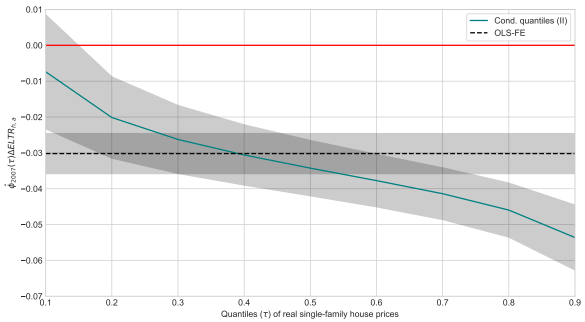
(d) 2003



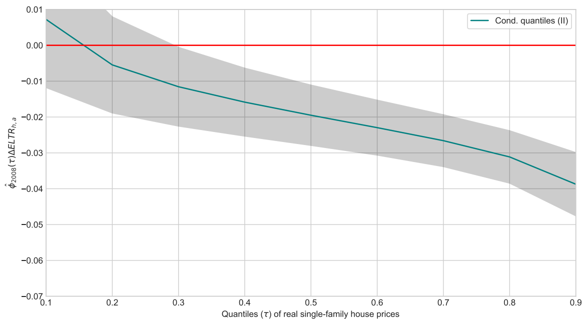
(e) 2005



(f) 2006



(g) 2007



(h) 2008

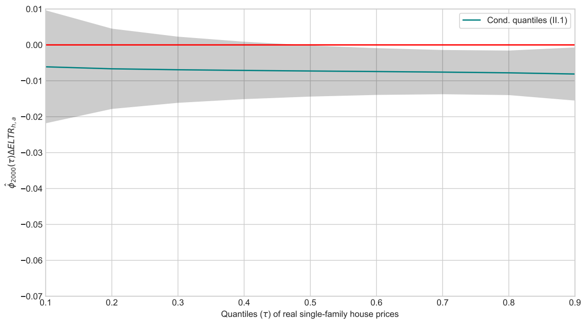
Note: Estimates of the changes to effective land tax rates in quantiles of real house prices with 95 percent confidence bands. Standard errors are clustered at the individual house level (”robust” standard errors). Estimates are from the model specificied in equation (3).

A.3.1 Conditional quantiles with changes to income tax

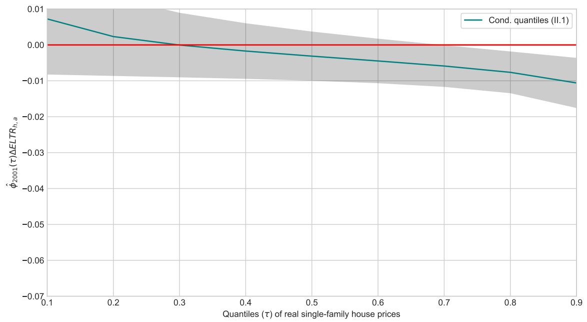
$$\ln P_{h,a,t}(\tau) = \beta_0(\tau) + \alpha_a(\tau) + \gamma_t(\tau) + \sum_{t=2000}^{2008} \phi_t(\tau)\Delta ELTR_{h,a} + \beta_1(\tau)\ln V_{01h,a} + \sum_{t=2005}^{2008} \psi_t(\tau)\Delta SERVICE + \epsilon_{h,a,t}(\tau) \quad (6)$$

With the restriction $\phi_{2004}(\tau) = 0$. ψ_t capture the potential gradual effect of differences in municipal services, proxied by the change to income tax as argued in Section 4.3.

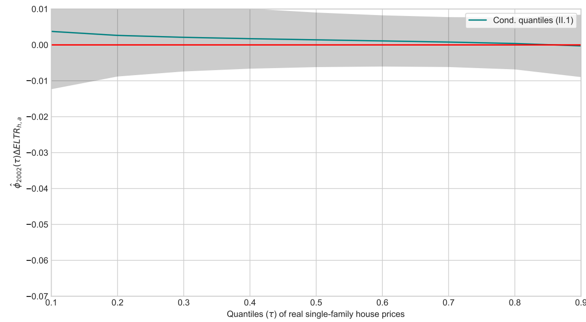
Figure 7: Robustness checks: Quantile treatment effects, within-quantile-fixed effects



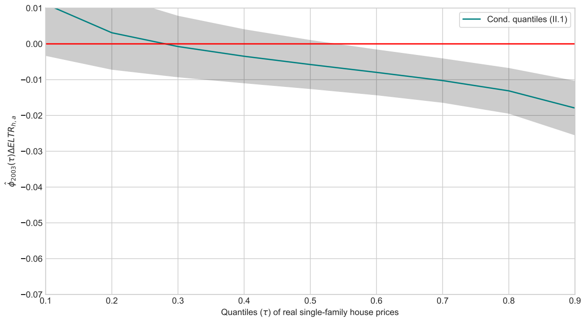
(a) 2000



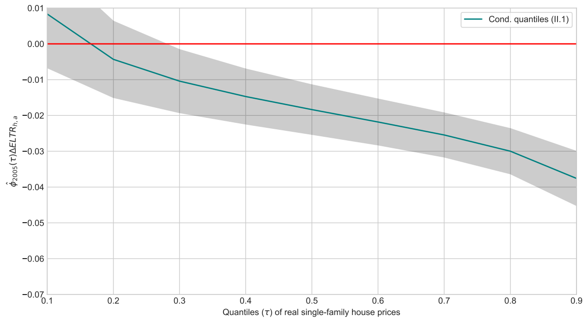
(b) 2001



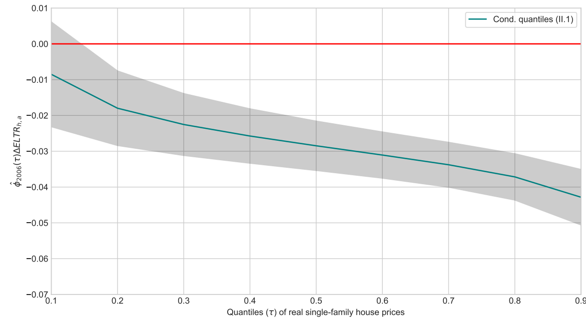
(c) 2002



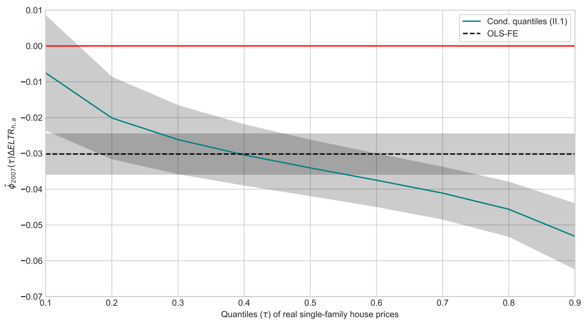
(d) 2003



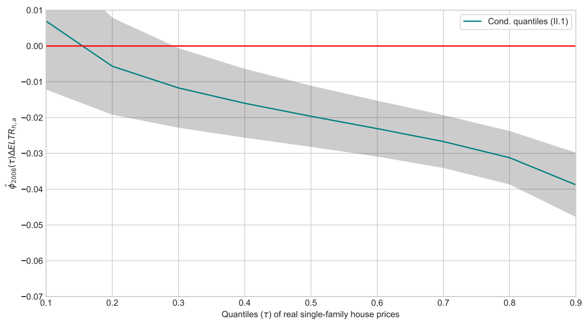
(e) 2005



(f) 2006



(g) 2007



(h) 2008

Note: Estimates of the changes to effective land tax rates in quantiles of real house prices with 95 percent confidence bands. Standard errors are clustered at the individual house level ("robust" standard errors). Estimates are from the model specificied in equation (6).