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Regional Danish housing booms and the effects of financial deregulation and expansionary economic policy

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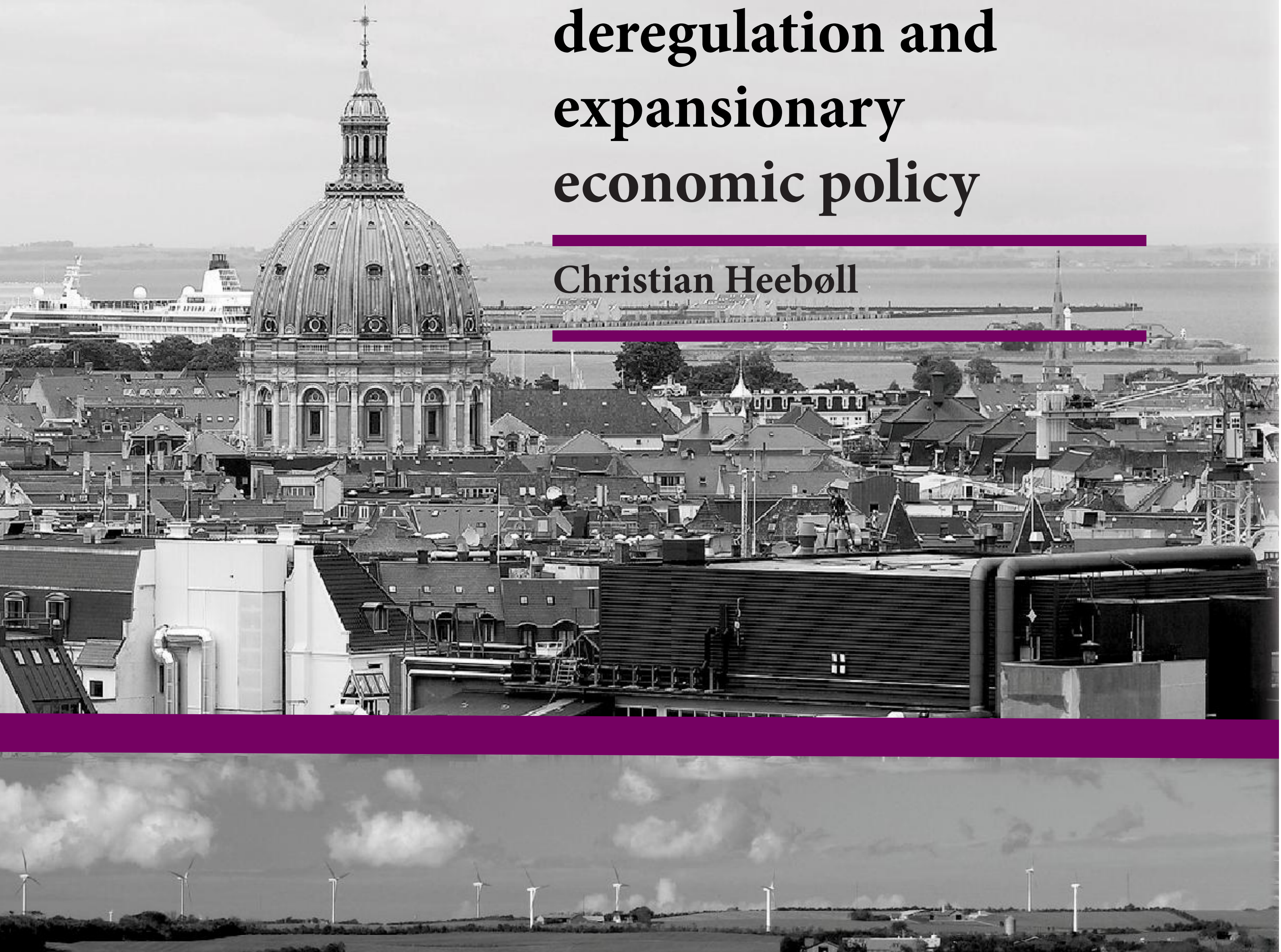

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Abstract: Using panel restricted standard and global VAR models, we analyze the structures of 14 Danish housing markets from 1987 to 2012. These models are then applied to investigate the factors behind the diverse regional Danish housing price booms of the 2000s. We find indications of price ripple effects between markets, as well as heterogeneous market structures related to individual area characteristics. The predictive power and precision of the models significantly increases by using the GVAR and panel random coefficients modelling approach. Using the region specific price elasticities and counterfactual simulations, we find that a combination of financial deregulation and expansionary monetary policy was decisive in the pre-crisis housing price boom – especially in urban areas. In rural areas, prices are relatively more sensitive to income and unemployment rate changes and, hence, fiscal policy had a somewhat larger influence in these areas. The Danish property tax freeze from 2002 and onwards generally had a minor influence. However, it is found to be price destabilizing, having a larger effect in more booming housing markets.

JEL Classification: *C32; C33; C51; C52; G01; R21; R31*

Keywords: *Regional Boom-Bust Cycles; Ripple Effects; Global VAR; Random Coefficients Modelling*

Ikke-teknisk dansk resumé

Det danske boligmarked var i løbet af 0'erne karakteriseret ved voldsomme regionale boligprisudsving, med alvorlige konsekvenser for gennemslaget af den finansielle krise. Imens de reale boligpriser i København centrum steg med næsten 140 pct. fra 2000 til 2007, steg de med mindre end 25 pct. i flere områder i Jylland. I dette papir analyseres årsagerne til de kraftige boligudsving i 0'erne, samt de meget forskelligartede regionale tendenser set siden år 2000. Fokus er på betydningen af tre generelle politiske tiltag: *i*) Finansiel deregulering givet ved introduktionen af rentetilpasningslån (RTL) og afdragsfrie lån (AFL) i hhv. 1999 og 2003, *ii*) den relativt lempelige finans- og pengepolitik i midt 0'erne, samt *iii*) fastfrysningen af ejendomsbeskatningen fra 2002.

I papiret analyseres de regionale boligpriser for 14 danske amter fra 1987 til 2012 (kvartalsvis) ud fra fejlkorrektionsmodeller (CVAR). Motiveret af tidligere litteratur på området, modelleres effekten af introduktionen af AFL og RTL med udgangspunkt i minimum førsteårsydelsen på realkreditlån (jf. Dam et al. (2011)). Endvidere tages der hånd om pris-smitteeffekter (*ripple effects*) og indbyrdes afhængighed imellem de regionale boligmarkeder ved anvendelse af en global fejlkorrektionsmodel (GVAR) (jf. Pesaran et al. (2004)).

Sammenhænge imellem regionale priseffekter (*pris-elasticiteter*) og forskellige markedskarakteristika, giver information om prismekanismer og dynamik i forskellige områder (*storby-, forstads- og udkantsområder*). Yderligere udnyttes denne information til at pålægge panelrestriktioner på afgørende koefficienter i modellerne, for derved at opnå en bedre og mere eksakt prædiktion af de regionale priseffekter. Eksempelvis pålægges der restriktioner som sikrer, at regionale priseffekter af AFL og RTL er relateret til andelen af kreditbegrænsede boligkøbere i det givne område. Dvs. andelen af familier hvis boligefterspørgsel forventes at stige med indførelsen af de nye låneformer. Metodemæssigt benyttes en *random coefficients modelling* tilgang (RCM) (jf. Arellano and Bonhomme (2012) og Hsiao and Pesaran (2004)).

Analysen giver en række interessante resultater. For det første findes regionalt specifikke boligefterspørgselsrelationer for alle områder, med klare regionale tendenser. Den regionale prisfølsomhed over for indførelsen af AFL og RTL findes positivt relateret til andelen af kreditbegrænsede boligkøbere. Sidstnævnte er approksimeret ved andelen af førstegangskøbere med høj gæld ift. deres indkomst. Disse resultater er i overensstemmelse med resultater i tidligere amerikanske studier (jf. fx Wheaton and Nechayev (2008) og Anundsen and Heebøll (2013b,a)). Videre findes pris-smitteeffekter at være større i befolkningstætte områder samt områder med høj andelen af pendlere. Heraf er det første resultat i overensstemmelse med resultaterne i Vansteenkiste (2007) for det amerikanske boligmarked. Det andet resultat indikerer, hvordan storbyerne fungerer som epicentre, hvorfra de kraftige prisudviklinger først smitter til forstæderne – hvor folk stadig kan pendle til deres arbejde i storbyerne – og derfra videre ud i landet. Som det eneste område, findes boligpriserne i København centrum, individuelt set, ikke at være signifikant påvirkede af prisudviklingen i andre områder. Dette indikerer, at priserne i København centrum er ledende ift. prisudviklingen i resten af landet og ikke omvendt.

Ved simulering af boligprisudviklingen fra 2000 til 2007 findes modellerne at kunne forklare imellem 78 og 90 pct. af de regionale boligprisstigninger (afhængig af området). Dette er en ganske høj forklaringsgrad set ift. tidligere nationale analyser.

For at analysere effekten af de nævnte politiske tiltag, simuleres boligpriserne fra 2000 til 2007 under kontrafaktiske politiske scenarier. Resultaterne peger på, at introduktionen af AFL og RTL havde en central betydning for den nationale boligprisudvikling i 0'erne. Der findes dog store regionale forskelle i effekterne. De direkte priseffekter er centeret omkring Københavnsområdet og Aarhus, hvorimod andre områder hovedsagligt er påvirket indirekte, igennem pris-smitteeffekter. Storbyerne udmærker sig ved, at mange boligkøbere er førstegangskøbere, samt at folk typisk bruger en relativ stor andel af deres indkomst på bolig. Yderligere er storbyer karakteriseret ved en begrænset udbudsdynamik på kort og mellemlang sigt. Det gør, at priserne i højere grad skal tilpasse sig, når der forekommer store efterspørgselsstød – som fx ved indførsel af AFL og RTL. Desuden øger det risikoen for boligbobler. Disse forhold forklarer den store følsomhed over for ændringer i de finansielle forhold, samt hvorfor boligboblen synes at udspringe i Aarhus og Københavnsområdet. På dette punkt er resultaterne også i overensstemmelse med internationale boligmarkedsanalyser (jf. Anundsen and Heebøll (2013a) samt referencer deri).

Indførelsen af AFL og RTL har også medføret at boligpriserne betydelig mere følsomme overfor ændringer i den pengepolitiske rente. De lave renter fra 2004 til 2007 har bidraget væsenligt til prisudviklingen i 0'erne, og effekten blev tilmed forstærket af indførelsen af de nye låneformer.

Effekten af den lempelige finanspolitik i 0'erne synes at være mere begrænset, og i modsætning til pengepolitikken har finanspolitikken en relativt større effekt i udkantsområder. Dermed har de nye låneformer, og deraf den forhøjede rentefølsomhed, også en anden uheldig politisk implikation. I perioder med relativ lempelig pengepolitik – givet fra den Europæiske Centralbank (ECB) – vil en dansk finanspolitik, der søger at stabilisere den realøkonomiske udvikling (outputgabet), ikke længere være tilstrækkelig kontraktivt til at stabilisere boligmarkedet. Dette gælder især for storbyområderne.

Skattestoppet fra 2002 findes at have haft en mindre betydning for boligprisudviklingen i 0'erne. I forhold til de andre politiske indgreb analyseret i papiret har skattestoppet dog en uheldig karakter af en automatisk *de*stabilisator, hvor ejendomsbeskatningen falder, når prisen stiger og omvendt.

1 Introduction

In many industrial countries, the financial crisis of 2008 was greatly affected by regional booms and busts in housing prices (Allen and Carletti, 2010). This has been analyzed to a large extent in the case of US, where real housing prices increased by more than 100% in California and Miami from 2000 to 2007, and by less than 10% in states such as Indiana and Ohio (Anundsen and Heebøll, 2013b). Similar tendencies were seen in Denmark, where real housing prices increased by almost 140% in Copenhagen from 2000 to 2007, while they increased by less than 25% in several regions of Jutland (e.g. Viborg).

As found in Iacoviello and Neri (2010) and Claessens et al. (2011), most economists agree on the adverse macroeconomic effects of fluctuations in housing prices. However, there is still much disagreement when it comes to the underlying factors that drive regional imbalances. In the case of the US, Duca et al. (2011), Anundsen and Heebøll (2013b,a) and Favilukis et al. (2014) find that sub-prime credit was a central factor in explaining the regional booms. Taylor (2008) points to the significance of expansionary monetary policy, especially in conjunction with the regional US economic boom of, e.g., California. Others argue that the housing boom was due to the large current account imbalance from the late 1990s (see Bernanke (2005)). Similar disputes are present in the case of Denmark. Here, the housing boom may have been influenced by at least three types of policy interventions during the early 2000s: financial deregulation and the introduction of new mortgage types, expansionary monetary and fiscal policy, as well as a general tax freeze policy on property.

In this paper, we investigate these hypotheses regarding the regional Danish housing price booms of the 2000s. In doing so, we pay heed to market heterogeneity, price spillover effects between regional markets as well as possible identification problems when analyzing the effects of several simultaneous policy interventions. Specifically, we estimate a global VAR (GVAR) model on 14 heterogeneous Danish housing markets, in line with the ideas of Pesaran et al. (2004). We allow for a number of intra-regional demand factors, such as regional disposable income, unemployment rates, user costs of housing and – especially relevant for the effects of financial deregulation – the minimum first year mortgage yield (see Badarinza et al. (2013), Sørensen (2013) and Dam et al. (2011)). Inter-regional housing demand is modeled as spillover price effects from related housing markets, which is found to be important when analyzing regional housing markets (see e.g. Meen (2001)).

To optimize our model identification, we test and impose panel restrictions on essential long-run coefficients in line with the literature on random coefficients modelling (RCM) (see Arellano and Bonhomme (2012) and Hsiao and Pesaran (2004)). For example, the price elasticity related to the introduction of new mortgage types is restricted as a function of regional proxies, measuring the share of credit rationed agents. To analyze the importance of the model innovations related to the GVAR and RCM specifications we compare the models with and without price ripple effects, and with and without RCM panel restrictions.

Using the estimated models, we further simulate the regional Danish housing prices from 2000 to 2007 under different counterfactual scenarios. This allows us to validate our model specifications and answer detailed questions about the individual and combined significance of the three policy interventions, both for national and regional housing prices:

- The financial deregulation of the Danish mortgage market in the late 1990s and early 2000s.
- The expansionary monetary and fiscal policy in the mid-2000s.
- The tax freeze policy on property taxes implemented from 2002 and onwards.

There is a large and growing econometric literature on national and regional housing booms and the effects of different policy interventions. Ashworth and Parker (1997) find clear similarities in the market structures of 9 out of 11 UK housing markets using a regional CVAR approach. Anundsen and Heebøll (2013a) conduct a similar analysis on 100 US metropolitan areas from 1980 to 2010 in order to explore the regional effects of sub-prime lending. Here, the price formation is found to vary greatly across regional markets, where the influence of sub-prime lending depends on regional supply restrictions. Compared to the current study, their model does not use the panel structure and market heterogeneity as a means of identification. Furthermore, they do not account for ripple effects between the areas, which seem to have a significant impact when analyzing such closely-situated areas as the Danish regional markets.

In a related line of literature, attempts have been made to account for regional price spillover effects using a GVAR approach. Vansteenkiste (2007) analyzes the influence of national real interest rate shocks on housing prices in 31 US states from 1986 to 2005. Here, she finds strong price spillover effects from states with lower land supply elasticities, such as California. However, the price effect of national interest rate changes is generally found to be small, suggesting that monetary policy was not a key factor in the US housing boom of the 2000s. Vansteenkiste and Hiebert (2011) do a similar analysis for the euro-area on a country level, finding a much weaker link between euro area countries than in the case of US states. This makes sense, as housing services in less related markets are weaker substitutes. From this perspective, we might expect an even larger inter-regional dependence between Danish housing markets. Compared to these earlier GVAR studies, we are also concerned with the heterogeneity of long-run housing price formation.

In the macro-econometric literature in general, a range of papers have utilized the GVAR model to analyze global macroeconomic development (see Pesaran et al. (2004) and Dees et al. (2007) and references therein). Another branch of the literature has applied RCM restrictions to time-series models (see e.g. Lin and Ng (2012)). However, this is – as far as we know – the first paper that attempts to combine the GVAR and RCM approach and to analyze the cointegration structure of a GVAR model.

The paper offer several contributions, relevant for both the literature on regional housing markets, as well as applied macro-econometrics. First, we find meaningful heterogeneous market structures for all areas including significant price ripple effects. The market structures are found to follow regional patterns, where, e.g., the effects of new mortgage types are found to be closely related to proxies for the share of credit-rationed agents. In this context – compared to standard regional CVAR models – the model innovations of the GVAR and panel RCM restrictions prove to be important for the predictive power and precision of the model, and to some extent the results. Generally all models, and especially the GVAR, are better at explaining the housing prices in rural areas compared to urban areas. In line with Abraham and Hendershott (1996) and Anundsen and Heebøll (2013a) we find that urban areas were more affected by the extensive financial deregulations during the 2000s, have stronger tendencies for housing price bubbles and do seem to lead the price developments in the rest of the country. This may explain the model's lower predictive power of the housing prices in urban areas.

As found in Dam et al. (2011), our results suggest that financial deregulation was a primary driver of the Danish housing price boom of the 2000s. That said, the regional direct impacts are closely related to the regional shares of credit-rationed buyers, which is high in markets in and around Copenhagen and Aarhus. However, allowing for price spillover effects in the GVAR model, rural areas are strongly affected indirectly. These results partly explain why the housing price boom was so much larger and seems to have originated in the center of Copenhagen and Aarhus. At this point, the lesson from the Danish experience is similar to the US, that political authorities have to recognize the potential instability related to financial deregulations and innovations (Duca et al., 2010; Anundsen and Heebøll, 2013b). While the property tax freeze from 2002 had a small aggregate impact, it is found to be price-destabilizing, having a relatively large effect in the regions where prices increase the most – again, the markets in and around Copenhagen. In contrast to the other political interventions analyzed in the paper, the tax freeze policy has an unfortunate structural feature, meaning that it ”automatically” will destabilize prices going forward – when prices increase taxes decrease and *vice versa*. Hence, from the objective of achieving a more stable housing price development, there are clear policy incentives to abolish the nominal tax freeze.

In contrast to the results of Vansteenkiste (2007), we find significant effects from expansionary monetary policy, especially in urban areas. The effects have even increased following the financial deregulation – especially the introduction of ARM. In that sense the effects monetary policy and financial deregulations are found to be mutually reinforcing. The effect of fiscal policy is found to be smaller in general but relatively large in rural areas. Together, these results also have some unfortunate policy implications. During times of expansionary monetary policy set by the ECB, a counteracting fiscal policy set to stabilize the Danish output gap will no longer be sufficiently contractionary to stabilize the Danish housing markets.

The remainder of the paper is structured as follows. In section 2, we describe the regional developments in Danish housing markets as well as the important economic policy interventions. In Section 3, we discuss the relevant theoretical literature and Section 4 explains our econometric model. In Section 5, we describe the data and in Section 6 and 7 we estimate a regional CVAR and GVAR model. Section 8 shows the results of simulations and counterfactual political scenarios while Section 9 concludes.

2 The Danish housing market

In this paper, we explore the formation of housing prices in 14 Danish regions.[1] The graph to the left in Figure 1 shows the evolution of quarterly real house prices in four of these regions throughout our sample period from 1987 to 2012. The 2000s in particular stand out as a period during which prices diverged greatly across the different regions, and from 2004 to 2010 we see a clear boom-bust cycle, especially in Copenhagen. The size of the regional housing booms (real price growth from 2000 to 2007) is further depicted for the 14 areas in the map to the right in Figure 1. Clearly, the boom was region specific and largest in the center of Copenhagen, smaller in the areas around Copenhagen, and smallest in the western regions of Jutland (Viborg Amt). This may indicate ripple effects between the areas, with price spillover effects from Copenhagen and Aarhus to closely situated areas.

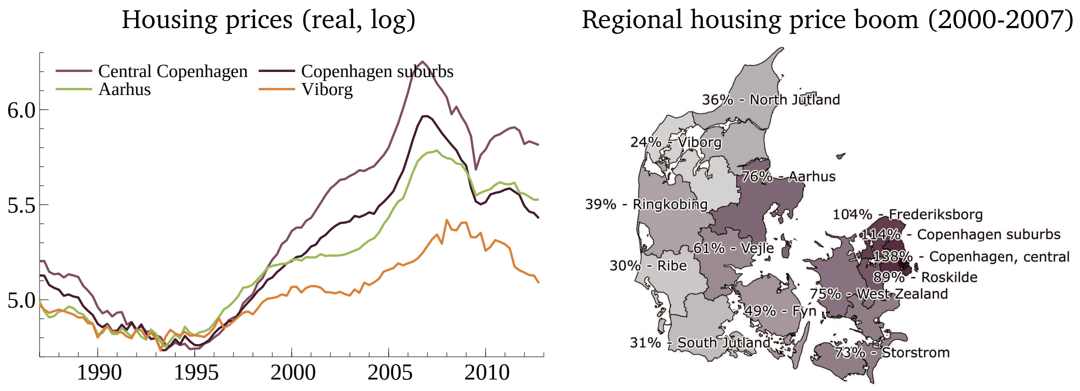
The Danish housing boom may have been the result of at least three general policy interventions, all of which mainly affected housing prices from the beginning of the 2000s. In the following, we will discuss each of these in turn, with a specific focus on counterfactual policy scenarios, to be analyzed later using the estimated housing models.

2.1 Financial deregulation

In Denmark, owner-occupied home financing consists of a two-layer system, where up to 80% of the value of a property can be financed through covered mortgage bonds.

[1]We consider the former 14 Danish counties (*amter*), including Copenhagen and Frederiksberg municipality but excluding Bornholm. These were subdivisions of metropolitan Denmark used until 2006. See Appendix A for details.

Figure 1: Regional Danish housing prices and housing price booms



Note: The data sources will be explained later.

Here, a *balance principle* imposes a strict matching rule between the mortgage loans and mortgage bonds, which makes the system transparent and secure, with conditions and interest rates close to those of other bond markets.

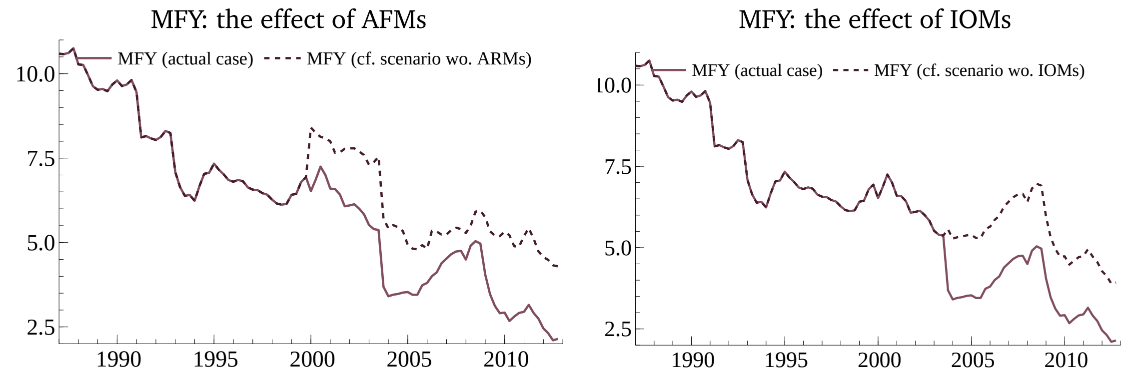
Traditionally, these bonds were offered with fixed interest rates and annuity payments up to a 30-year horizon. However, financial deregulation during the 1990s and 2000s allowed mortgage banks to issue two new types of mortgages: *adjustable-rate mortgages* (ARM) offered from 1999, and *interest-only mortgages* (IOM) offered from 2003.[2,3] Both types of mortgages allow for a much higher debt-to-payment ratio, which may especially affect housing prices through the perceived purchasing power of credit-rationed and irrational agents (see Badarinza et al. (2013) and Sørensen (2013)). As done previously in Dam et al. (2011), we analyze the price effects of these mortgages by means of the *minimum first year mortgage yield*, including property taxes (MFY). Further, we condition on regional instruments measuring the share of credit-rationed agents, as will be considered later.

To illustrate possible effects of different policy interventions, we consider counterfactual scenarios of key economic variables assuming that the given policy was not introduced, *ceteris paribus*. In the case of ARMs, the graph to the left in Figure 2 compares two scenarios: *i*) MFY in the actual case and *ii*) MFY in the counterfactual scenario where ARM was not introduced, assuming that the lowest interest rate in that case would have been equal to the 30-year mortgage interest rate throughout the sample period. Here, we assume *ceteris paribus* that the 30-year mortgage rate is unaffected by the introduction of ARMs. One may argue that if the large credit boom in Denmark in the 2000s was partly due to the introduction of ARMs, the total amount of mortgage debt

[2]The legislation for ARM in Denmark was introduced in 1996, but in practice these loans were not offed before 1999. The IOM was introduced and offered in October 2003.

[3]During the 2000s, other more exotic mortgage types emerged. However, generally, we see these as combinations of adjustable rate and fixed rate mortgages as well as the option to defer amortization.

Figure 2: Minimum first year mortgage yield (MFY) (for central Copenhagen)



Note: For data sources and details see Appendix D.

might have been smaller in the counterfactual scenario. Even though Denmark is a small open economy, this might have affected the 30-year mortgage rate. We therefore view this as a ”high-end” scenario.

As seen, the counterfactual scenario diverges gradually from the actual case from 1999 and onwards, after which housing buyers were able to utilize more risky mortgage bonds, with as short as a one-year adjustment period (*F1 mortgages*). The ARMs allowed for a 1 – 2 pp. lower first year nominal yield compared to fixed rate mortgages. The ARMs were widely used from 2001 and even more markedly from 2004, at which point more than 40% of the existing pool of mortgage bonds consisted of ARMs. By the end of 2012, this number was up to almost 70%.[4]

Similarly, the graph to the right in Figure 2 shows the MFY in the actual case and in the case had IOM not been introduced – i.e. where the lowest possible amortization equaled a 30-year annuity throughout the sample period. From 2003, we observe a sudden large divergence, as housing buyers were offered the option to defer amortization for up to a decade. This immediately lowered the MFY by about 2 pp., and these mortgages steadily became popular after 2003. In 2008, 50% of the existing pool of mortgage bonds consisted of IOMs.[5] Since then, the share has increased only slightly.

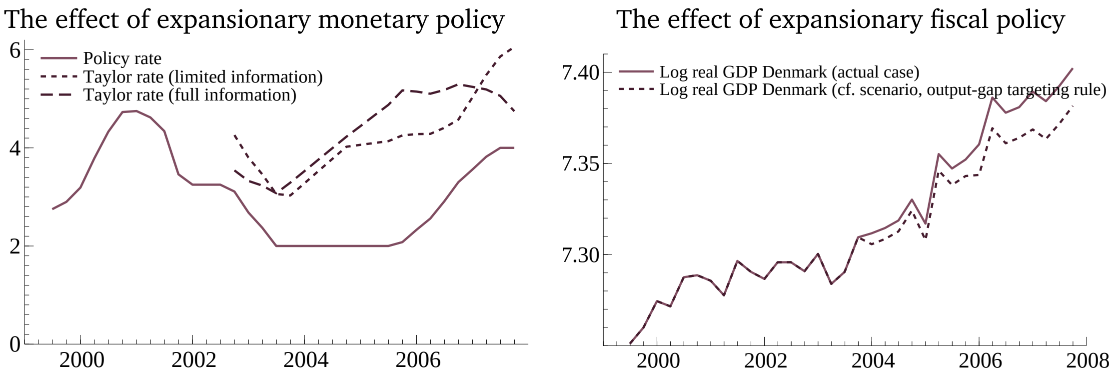
2.2 Monetary and fiscal policy

Another important aspect is the monetary and fiscal policy. Denmark follows a fixed exchange rate policy against the euro. However, Danish economic conditions differed from the conditions in the euro-zone during the pre-crisis period, and the monetary policy was rather expansionary (see also Ravn (2012)). In line with the ideas of Clarida

[4]Source: The Danish Mortgage Bank Advisory (*Realkreditrådet*).
[5]Note: Many mortgages are financed by a combination of both loan types.

et al. (1998) and Sturm and Wollmersäuser (2008), Heebøll (2014) estimates a standard Taylor-rule for the ECB, applied to the macroeconomic data for the euro-area as a whole from 1999 to 2007. Further, applying this rule to Danish economic conditions, Heebøll finds the optimal monetary policy for Denmark according to the Taylor principle of the ECB. The graph to the left in Figure 3 shows the policy rate in the actual case and in the counterfactual scenario where the interest rate had followed this Taylor rule – both given the information available at the time (limited information) and given the revised inflation and output gap figures (full information).[6] As seen, both counterfactuals diverge from the actual scenario from 2003 and onwards, and especially so in 2006 and 2007, where the deviation of the full information counterfactual was almost 2 pp.

Figure 3: The effects of monetary and fiscal policy interventions



Note: The effect of expansionary monetary policy is only calculated from 2002 and onwards. For data sources and details see Appendix D. The full information is the scenario using the revised output-gap and inflation figures. The limited information is the scenario using only data available in real time.

In fixed exchange rate regimes, each individual country should pursue a fiscal policy which counteracts such regional monetary imbalances. However, as was the case for several countries in the euro-zone, Danish fiscal policy was rather expansionary during the pre-crisis period. To analyze the effect of expansionary fiscal policy through the pre-crisis period, we will consider to what extent fiscal policy (measured as the first year impact on GDP) deviates from an output-gab stabilizing fiscal policy rule developed by DØR (*The Danish Economic Council*) (see Linaa et al. (2008) and calculations in Kraka (2012)). The graph to the right in Figure 3 shows Danish real GDP in the actual case and in the counterfactual scenario according to the fiscal policy rule of DØR. There is a significant effect of expansionary fiscal policy on real GDP from 2004 and until the outset of the financial crisis. In the counterfactual scenario, real GDP would have been about 2% lower in 2007.

These expansionary economic policies may have affected the housing market through several channels – e.g. income, unemployment rates and user costs – but, as for the effect of financial deregulation, they may also have had a region specific effect. The

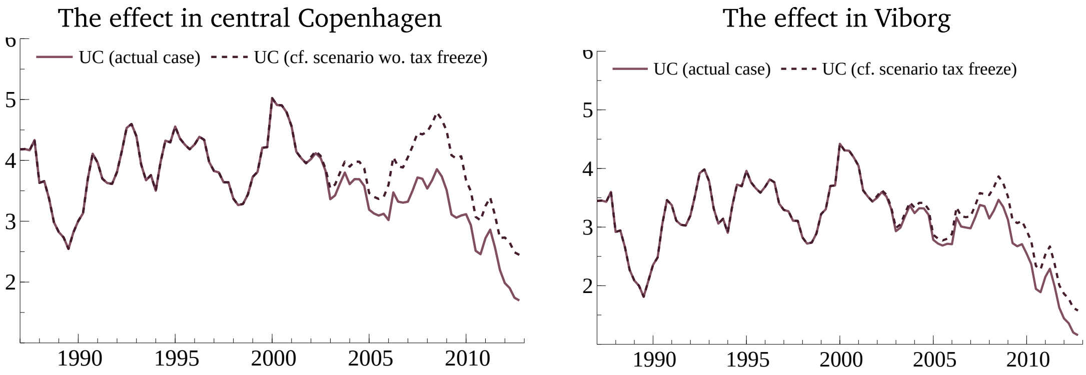
[6]For the Danish economy we use the expectations and revised figures of the Danish Ministry of Finance.

formation of housing demand may, e.g., be determined in part by the regionally specific risk of unemployment spells, as well as the regional income distribution.

2.3 The property tax freeze

A third and hotly debated topic in Danish media is the general tax freeze policy implemented by the Danish government from 2002 and onwards. This meant that property taxes were fixed to their 2002 nominal levels, which gradually eroded the effective tax rate as housing prices increased. Theoretically, this affects housing prices through the user costs and MFY – possibly also conditioned on regional market characteristics.

Figure 4: The effects of the property tax freeze on regional real user costs



Note: For data sources and details see Appendix D.

Making use of Danish register data on all owner-occupied homes in Denmark, Heebøll et al. (2013) have calculated the regional property taxes on new home purchases in the actual case and in the counterfactual scenario where the tax policy of 2001 continued throughout the sample period .[7] For the two extreme cases – Copenhagen and Viborg – the standard real user costs are shown in Figure 4, in both the actual and counterfactual scenario.[8] It can be seen that the effect of the property tax freeze is significantly larger in central Copenhagen where, at the peak of the housing boom in 2008, the user costs would have been about 1% higher had the tax freeze policy not been introduced. For Viborg, the difference was only 0.4%. This is due to the fact that the property tax freeze was price destabilizing, having the largest impact in areas where the housing prices increased the most.

Later, these counterfactual scenarios will be analyzed in detail to determine the effects of the different policy interventions on regional housing prices.

[7] In Denmark the property tax consists of a central government property value tax (*ejendomsværdiskat*) based on the public property assessment and a regional specific municipal land tax (*grundskyld*). Both types of taxes are included in the calculations (see Heebøll et al. (2013)).

[8] The standard real user cost is more specifically defined later as the sum of property taxes and the fixed real interest payments after tax deductions. Expected capital gains are not included.

3 Theoretical motivation

Theoretically, housing prices in each region are determined through three broad channels:

1. Intra-regional housing demand, related to region specific conditions.
2. Price spillovers from neighboring and related housing markets.
3. National economic policy interventions as discussed above.

These will be discussed in the following, focusing on how to model the effects in the global panel VAR model.

3.1 Intra-regional housing demand

In econometric analyses of housing prices, it is typical to start with a representative agent model, giving the following inverse housing demand function (see e.g. Meen (1990)):

$$p_{i,t} \quad = \quad \beta_{i,h} h_{i,t} + \beta_{i,UC} UC_{i,t} + \beta_{i,y} y_{i,t} \tag{1}$$

Here, subscript *i* indicates the area, $p_{i,t}$ is the housing prices for area *i* at time *t*, $h_{i,t}$ is the housing stock, $UC_{i,t}$ is the real user cost of housing services – including property taxes and real interest payments on a 30 year fixed-rate loan after tax deductions – while $y_{i,t}$ denotes disposable income.[9] Housing supply and user costs are expected to affect prices negatively while the disposable income is expected to have a positive effect, i.e. $\beta_{i,h}$, $\beta_{i,UC} < 0$ and $\beta_{i,y} > 0$. However, a demand function like (1) does not offer an explanation of heterogeneous markets with regional effects of policy interventions. Further, it assumes that all agents are financially unconstrained, leaving no room for the role of financial deregulation. In this paper, we therefore take a heterogeneous agent approach, in line with Badarinza et al. (2013) and Sørensen (2013).

Specifically, we will assume that only some share of the agents in each area *i;* ν_i, are financially unconstrained with a housing demand dependent on the real user cost; $UC_{i,t}$, as denoted in (1). The remaining share of the agents; $1 - \nu_i$, are financially constrained. Here, we are motivated by the results in Badarinza et al. (2013), who find that financially constrained agents typically follow a current cost minimization approach, i.e. they are short sighted consumers. Hence, instead of the real user costs, we will assume

[9]Some econometric models of housing prices also include the expected capital gain in the user cost. This is not done in the current analysis, as they are picked up as adaptive expectations in the short-run dynamics (see Abraham and Hendershott (1996)).

that the housing demand of these agents depends on the minimum first year mortgage yield; $MFY_{i,t}$. From this perspective, we may consider a demand function including a *quasi-user cost* measure:[10]

$$QUC_{i,t} = \nu_i UC_{i,t} + (1-\nu_i)\, MFY_{i,t} \qquad (2)$$

where $1-\nu_i$ is a region specific weight, given by the share of agents that are financially constrained. In practice, the financial conditions of housing buyers are, of course, not as clear-cut. Some share of the agents are to be considered financially constrained, but they may not be truly short sighted, i.e. they focus only partly on the $MFY_{i,t}$ and partly on $UC_{i,t}$. However, we assume that there exists some mapping into the discrete approximation given in (2). In the empirical model the effects of financial deregulation will affect prices only through the $MFY_{i,t}$, and hence the estimation of the ν_i's is crucial to the results of the model. Acknowledging this, we apply different instruments to measure these region specific characteristics cross-sectionally.

Furthermore, we also allow for an effect from the unemployment rate, in order to measure income uncertainty. For each region, we assume that some share of the housing buyers are at risk of becoming unemployed and, in addition to their disposable income, their housing demand also depends on the unemployment rate, u_i.

By extending (1) to take account of agents being financially constrained and agents being at risk of unemployment, we formulate the following indirect demand for housing:

$$p_{i,t} = +\beta_{i,h} h_{i,t} + \beta_{i,UC} UC_{i,t} + \beta_{i,MFY} MFY_{i,t} + \beta_{i,y} y_{i,t} + \beta_{i,u} u_{i,t}. \qquad (3)$$

Here the price effects of the unemployment rate and MFY are both expected to be negative, i.e. $\beta_{i,h}$, $\beta_{i,UC}$, $\beta_{i,MFY}$, $\beta_{i,u} < 0$ and $\beta_{i,y} > 0$. Here, $\beta_{i,UC}$ and $\beta_{i,MFY}$ are functions of ν_i in (2), i.e. dependent on market characteristics such as the share of buyers that are financially constrained. Further, $\beta_{i,y}$ and $\beta_{i,u}$ may also be region dependent.

3.2 Price ripple effect between regional markets

An important aspect when considering local housing markets is the influence of price ripple effects and ultimately price convergence across different areas. These may work through several channels, most importantly that agents, *ceteris paribus*, tend to migrate to the areas where prices are lower. In the ultimate case, this motivates the Law of One Price (LOOP) – only in this case, the buyer moves instead of the product. Other channels are discussed in Meen (1999, 2001) and Holmes et al. (2011).

[10]From the theoretical model in Sørensen (2013), this corresponds to the corner solution in the extreme scenario where the financially constraint agent are truly short sighted, i.e. they act only on the basis of current cost minimization.

Translating this into an econometric framework, one may argue that price convergence will encourage the following long-run relation (see e.g. Holmes and Grimes (2008) and the references therein):

$$p_{i,t} = \beta_{i,*} p^*_{i,t} \tag{4}$$

where $p^*_{i,t}$ measures housing prices in markets that are deemed as close substitutes to market i. As for (3), the specific influence of other markets; $\beta_{i,*}$, will depend on different market features creating proximity between markets.

Both intra-regional housing demand and ripple effects may be important when studying regional housing markets. In fact, disregarding one of them could result in a sizeable bias or spurious results (see Meen (1999)). Having said this, it is not typical to study both types of long-run relationships – (3) and (4) – in one and the same model, and it is not clear how or to what extent prices should converge to the regional fundamentals vs. the prices of related markets. It is, however, clear that prices can only converge to one long-run relation. Acknowledging this, we expect prices in each area to follow some combination of (3) and (4) in the long run, i.e. a combination of the intra- and inter-regional demand for housing in the area.

4 Econometric method

Our empirical method combines two separate approaches. First, we apply an unrestricted global VAR (GVAR) model approach to our sample of 14 regional Danish housing markets. As mentioned, a GVAR model is characterized by allowing for ripple effects between the areas. To analyze the importance of these, we also compare with a standard CVAR model, i.e. the model without the ripple effects. Further, to ensure identification, we analyze and restrict the long-run coefficients across the individual areas based on a RCM approach.

4.1 The GVAR approach

To first estimate a time-series model for each housing market separately, we use a GVAR approach for a panel of $N + 1 = 14$ regions, in line with the ideas of Pesaran et al. (2004) and Vansteenkiste (2007). To analyze the theoretical relations (3) and (4), we primarily consider the long-run dynamics in the VECM-representation, and we will only have one endogenous variable in each region i, the regional housing price index; p_i.

Compared to a panel of regional CVAR models, the GVAR approach allow each regional model to be interconnected with all other regions. Specifically, this is handled by including *related area variables* measured as a weighted average of the respective variables in all other areas included in the model. To measure a price-ripple effect we will follow Vansteenkiste (2007) and include a *related area housing price* variable (only), defined as the 1/distance-weighted average of prices in all other areas in the model. A vector of foreign prices for all areas at time t can be represented as; $\mathbf{p_t}^* = w\mathbf{p_t}$, where $\mathbf{p_t}$ is the vector of the prices in all areas at time t and w is a weight matrix with zeros on the diagonal and 1/distance on the off-diagonal – normalized such that each row-sum equals unity:

$$w = \begin{bmatrix} 0 & w_{0,1} & \cdots & w_{0,N} \\ w_{1,0} & 0 & & w_{1,N} \\ \vdots & & \ddots & \vdots \\ w_{N,0} & w_{N,1} & \cdots & 0 \end{bmatrix} \tag{5}$$

To find the GVAR representation we first define the individual VARX$_i^*$ models for each area. This is similar to a standard VAR representation where we have the related area variables included as exogenous variables:

$$p_{i,t} = a_i D_{i,t} + \sum_{j=1}^{J_i^p} \Phi_{i,j} p_{i,t-j} + \sum_{j=0}^{J_i^*} \Phi_{i,j}^* p_{i,t-j}^* + \sum_{j=0}^{J_i^x} \Psi_{i,j} X_{i,t-j} + \epsilon_{i,t} \quad , \quad \forall i = 0, \ldots, N \tag{6}$$

Subscript i generally indicates the area, $X_{i,t}$ is a matrix of exogenous variables for area i at time t, $D_{i,t}$ is a vector of deterministic variables including a constant, possibly a trend, as well as impulse dummies reflecting extraordinary shocks to the model. The J_i^p, J_i^* and J_i^x are the lag-length related to p_i, p_i^* and $X_{i,t}$.

To reach the GVAR representation we define the contemporary feedback matrix; $A_i = [1, -\Phi_{i,0}^*]$, the general coefficients matrices for lagged endogenous variables: $B_{ij} = [\Phi_{i,j}, \Phi_{i,j}^*]$, $\forall j > 0$ and a 2×1 price-vector; $z_{i,t} = (p_{i,t}, p_{i,t}^*)$ that stacks the domestic and foreign prices. The price-vector $z_{i,t}$ is further represented using a selection weight-matrix and a vector of prices in all areas; $z_{i,t} = W_i \mathbf{p_t}$, where $W_i = [I_N^{i'}, w_i']'$ and $I_N^{i'}$ and w_i' are the i'th row of the identity matrix and w, respectively. Hence, in the case of e.g. the first area we have:

$$W_0 = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & w_{0,1} & \cdots & w_{0,N} \end{bmatrix} \tag{7}$$

Hereby we are able to write the full GVAR model in companion form by stacking all the individual VARX* models in (6):

$$\mathbf{G p_t} = \mathbf{a D_t} + \sum_{j=1}^{J^p} \mathbf{\Phi_j p_{t-j}} + \sum_{j=0}^{J^x} \mathbf{\Psi_j X_{t-j}} + \epsilon_t \tag{8}$$

where:

$$\mathbf{G} = \begin{pmatrix} A_0 W_0 \\ \vdots \\ A_N W_N \end{pmatrix}, \qquad \mathbf{\Phi_j} = \begin{pmatrix} B_{0j} W_0 \\ \vdots \\ B_{Nj} W_N \end{pmatrix}, \qquad \mathbf{\Psi_j} = \begin{pmatrix} \Psi_{0j} S_0 \\ \vdots \\ \Psi_{Nj} S_N \end{pmatrix} \tag{9}$$

and $J^p = \max_{i=0,\ldots,N}\{J_i^p, J_i^*\}$, $J^x = \max_{i=0,\ldots,N}\{J_i^x\}$, while S_i is a selection matrix that ”picks out” the exogenous variables for area i from the global $\mathbf{X}$-matrix.

In order to analyze the cointegration structure of the model, we will also consider the individual models in (6) on a ECMX$_i^*$-representation:

$$\Delta p_{i,t} = a_i D_{i,t} + \alpha_i \beta_i^{'} \tilde{X}_{i,t-1} + \sum_{j=1}^{J_i^{p-1}} \Gamma_{i,j} \Delta p_{i,t-j} + \sum_{j=0}^{J_i^*-1} \Gamma_{i,j}^* \Delta p_{i,t-j}^* + \sum_{j=0}^{J_i^x-1} \Upsilon_{i,j} \Delta X_{i,t-j} \tag{10}$$

$\forall i = 0, \ldots, N$, where $\tilde{X}_{i,t} = [p_{i,t}, p_{i,t}^*, X_{i,t}]$ and $\beta_i^{'}$ and α_i measure the long-run and error-correction coefficients. From rewriting (6) we have:

$$\alpha_i \beta_i^{'} = \left[\sum_{j=1}^{J_i^p} \Phi_{i,j} - I, \sum_{j=0}^{J_i^*} \Phi_{i,j}^*, \sum_{j=0}^{J_i^x} \Psi_{i,j} \right], \qquad \Gamma_{i,j} = -\sum\nolimits_{l=j+1}^{J_i^p} \Phi_{i,l} \tag{11}$$

$$\Gamma_{i,j}^* = \begin{cases} {}_{l=j+1}^{J_i^p} \Phi_{i,l}^* & \forall j > 0 \\ \Phi_{i,0}^* & \forall j = 0 \end{cases}, \quad \Upsilon_{i,j} = \begin{cases} -\sum\nolimits_{l=j+1}^{J_i^x} \Psi_{i,l} & \forall j > 0 \\ \Psi_{i,0} & \forall j = 0 \end{cases},$$

$\forall i = 0, \ldots, N$. Further we can find the GECM-representation:

$$\mathbf{G \Delta p_t} = \mathbf{a D_t} + \alpha \beta^{'} \mathbf{\tilde{X}_{t-1}} + \sum_{j=1}^{J^p-1} \mathbf{\Gamma_j \Delta p_{t-j}} + \sum_{j=0}^{J^x-1} \mathbf{\Upsilon_j \Delta X_{t-j}} + \mathbf{\epsilon_t} \tag{12}$$

where $\mathbf{\tilde{X}_t} = [\mathbf{p_t}, \mathbf{X_t}]$ and, from rewriting (8), we have; $\alpha\beta^{'} = [\sum_{j=1}^{J^P} \mathbf{\Phi_j} - \mathbf{G}, \sum_{j=0}^{J^x} \mathbf{\Psi_j}]$, $\mathbf{\Gamma_j} = -\sum_{l=j+1}^{J^P} \mathbf{\Phi_l}$, $\mathbf{\Upsilon_j} = -\sum_{l=j+1}^{J^x} \mathbf{\Psi_l}$, $\forall j > 0$ and $\mathbf{\Upsilon_0} = \mathbf{\Psi_0}$. Another representation of these matrices would result if we define $C_{ij} = [\Gamma_{i,j}, \Gamma_{i,j}^*]$, $\forall i = 0, \ldots, N$ and stack the individual models in (10):

$$\mathbf{\Gamma_j} = \begin{pmatrix} C_{0j}W_0 \\ \vdots \\ C_{Nj}W_N \end{pmatrix}, \quad \mathbf{\Upsilon_j} = \begin{pmatrix} \Upsilon_{0j}\rho_{x0} \\ \vdots \\ \Upsilon_{Nj}\rho_{xN} \end{pmatrix}, \tag{13}$$

$$\alpha = \begin{pmatrix} \alpha_0 & 0 & \cdots & 0 \\ 0 & \alpha_2 & & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \cdots & \alpha_N \end{pmatrix}, \quad \beta = \begin{pmatrix} \tilde{W}_0\beta_0 \\ \tilde{W}_1\beta_1 \\ \vdots \\ \tilde{W}_N\beta_N \end{pmatrix}.$$

where $\tilde{W}_i$ is a selection-weight matrix that "picks out" the $\tilde{X}_{i,t}$ from $\tilde{\mathbf{X}}_\mathbf{t}$.

In this paper, we are specifically interested in the structure of the long-run relations in β, as discussed in the theoretical Section 3. Hence, the estimation, specification and identification of GVAR models will be done on the basis of the 14 partial ECMX$_i^*$ models in (10). These individual models will later be re-parameterized to the GECM form in (12), which is then used to analyze the system by price simulations under different counterfactual scenarios.

4.2 The weight matrix and stability of the GVAR

Regarding the definition of the foreign area prices, p^*, we have estimated the model including several different weighting schemes, motivated by the previous literature: *i*) geographical distance between the areas as considered by Vansteenkiste (2007), *ii*) geographical distance adjusted for population size as used in Beenstock and Felsenstein (2007) and *iii*) a measure for close neighbors as suggested by Kuethe and Pede (2010). Here we have decided to use the *one divided the distance measure* of Vansteenkiste (2007), since this results in the highest sum of log-likelihood contributions from the individual unrestricted $\mathrm{ECMX^*}_i$ models and a fairly stable GVAR model.[11]

Further, in contrast to most previous analyses that apply the GVAR model, Danish housing markets are rather closely situated and related, implying that the price spillover effects can make the GVAR model unstable. This will occur if the two-way ripple price effects from one area to the rest of the country and vice versa are mutually accelerating. Hence, small price fluctuations could accelerate into exploding prices. Econometrically, this happens if the **G**-matrix in (12) and (8) is almost singular. In a model estimated simultaneously like a CVAR, we would handle such problems by restricting the matrix. However, the GVAR model is estimated partially, one area at the time based on the $\mathrm{ECMX^*}_i$ models in (10). Hence, it is not possible to restrict the model this way. Instead,

[11]Here we have also done some robustness analyses, finding that the general results are not changed from using any of the other two types of weighting matrixes suggested. Of course one could think of other weight matrices, e.g. where areas are more related to other areas with the same characteristics.

Table 1: Restricted weight matrix

	Cph.C.	**Cph.sub**	**Fr.borg**	**Rosk.**	**Aarhus**	**Fyn**	**Vejle**	**W. Zea.**	**N. Jut.**	**S. Jut.**	**Ribe**	**Storst.**	**Viborg**	**Ringk.**
Cph.C.	0	0.85	0	0	0.15	0	0	0	0	0	0	0	0	0
Cph.sub	0.86	0	0	0	0.14	0	0	0	0	0	0	0	0	0
Fr.borg	0.41	0.59	0	0	0	0	0	0	0	0	0	0	0	0
Rosk.	0.31	0.36	0.34	0	0	0	0	0	0	0	0	0	0	0
Aarhus	0.23	0.20	0.25	0.31	0	0	0	0	0	0	0	0	0	0
Fyn	0.13	0.12	0.14	0.19	0.43	0	0	0	0	0	0	0	0	0
Vejle	0.07	0.06	0.08	0.10	0.35	0.34	0	0	0	0	0	0	0	0
W. Zea.	0.10	0.10	0.11	0.19	0.16	0.24	0.10	0	0	0	0	0	0	0
N. Jut.	0.06	0.05	0.06	0.07	0.30	0.15	0.18	0.12	0	0	0	0	0	0
S. Jut.	0.04	0.04	0.04	0.05	0.14	0.18	0.29	0.10	0.12	0	0	0	0	0
Ribe	0.03	0.03	0.03	0.04	0.11	0.11	0.20	0.07	0.13	0.25	0	0	0	0
Storst.	0.10	0.08	0.08	0.16	0.07	0.10	0.06	0.16	0.06	0.06	0.05	0	0	0
Viborg	0.03	0.02	0.03	0.03	0.12	0.08	0.14	0.05	0.20	0.10	0.15	0.05	0	0
Ringk.	0.02	0.02	0.02	0.02	0.07	0.06	0.11	0.04	0.10	0.09	0.19	0.03	0.24	0

Note: The table shows the weight matrix related to foreign areas prices; w. The foreign area prices are given as; $\mathbf{p_t}^* = w\mathbf{p_t}$.

we have imposed a strict causal structure, implying that the weight matrix w in (5) is a lower triangular matrix. Considering the ripple tendencies and sizes of the regional housing booms shown in Figure 1, it seems reasonable to assume that prices in urban areas are not significantly affected by prices in suburb areas, that suburb areas are not significantly affected by prices in rural areas, etc.[12] On these grounds, we assume that the weights follow a one over distance measure as used in Vansteenkiste (2007), but only with non-zero weights on areas that are more densely populated. The only exceptions are the cases of what is considered to be geographical centers, including Copenhagen center and suburbs as well as Aarhus. Between these regions we allow ripple effects working in all directions.[13] This is done to make sure that Copenhagen center is also allowed to be affected by foreign prices.[14] The ordering of the ripple effects (by population density) are shown in the map in Figure 5, while the restricted weight matrix (w) is shown in Table 1.

4.3 Total impact coefficients

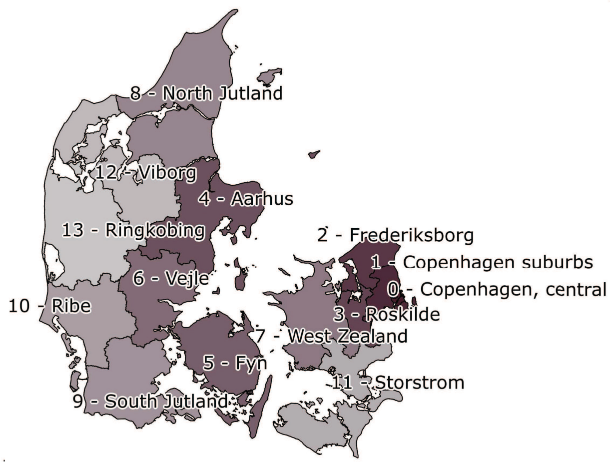
When analyzing and comparing the GECM model with related standard ECM models – i.e. where the coefficient on p^* is restricted to zero – it is essential to note the difference between the interpretation of the long-run coefficients. To illustrate, let us consider a system consistent of $N+1$ regional ECM models, including the non-stationary endogenous variable; $q_{i,t}$, and the non-stationary exogenous variable; $x_{i,t}$. As is often the case in regional analyses, assume that x is closely correlated across regions. This could, for

[12]This is also clear when considering the timing of the regional Danish housing booms of the 2000, where prices in Copenhagen and other larger cities seem to lead prices in suburbs and rural areas.

[13]By trying different more or less restricted weighting schemes it seems that the areas that cause the instability in the model are mostly rural areas and to some extent the far out suburbs of Copenhagen, especially Roskilde.

[14]If we use a weight matrix with a true triangular structure, it will have a zero-row in the case of Copenhagen center and the foreign area prices will be zero; $p^*_{0,t},\ \forall t = 1, \ldots, T$. In that case we would have an unbalanced panel.

Figure 5: Ordering of the ripple by population density



Note: The numbers indicate the ordering of the price ripple (by population density), as given in the (partly) triangular structure of the weight matrix, w, in Table 1.

example, be the interest rate, disposable income or the user cost of housing. Specifically, assume that we have:

$$x_{i,t} = \theta_i X_t + \epsilon_{i,t} \tag{14}$$

where X_t is a national variable and $\epsilon_{i,t}$ is a random error term. If x is (close to) a national variable, θ_i will be (almost) the same across areas, $\theta_i \approx \theta$, $\forall i = 1, \ldots, N$ and $\epsilon_{i,t} \approx 0$, $\forall i = 0, \ldots, N$, $\forall t = 1, \ldots, T$. Assume that there exists the following normalized long-run relationships between the two variables in each area:

$$q_{i,t} = \beta_{i,x} x_{i,t} \ , \quad \forall i = 0, \ldots, N \tag{15}$$

Similar to the focus of this paper, assume we are interested in analyzing the effects on $q_{i,t}$ of changes in the national variable X_t, e.g. as a result of national economic policy or financial deregulation. Given that the x_is are in logarithms, this can be analyzed by considering the $\beta_{i,x}$s, which are standard long-run elasticities.

Now, consider the case where we introduce ripple effects related to the endogenous variable; $q_t^* = wq_t$, as explained in the previous section. Further, assume that q_t^* significantly affects the long-run relationship in the model, and as such, instead of (15), we have the long-run relationships:

$$q_{i,t} = \tilde{\beta}_{i,x} x_{i,t} - \beta_{i,*} q_{i,t}^* \ , \quad \forall i = 0, \ldots, N \tag{16}$$

Here, one may be tempted to directly compare the CVAR and GVAR estimates, $\beta_{i,x}$ and $\widetilde{\beta}_{i,x}$. However, when analyzing the influence of national (or almost national) variables, these will have quite different economic interpretations. In the GVAR model, $\widetilde{\beta}_{i,x}$ is a partial elasticity that does not take account of $q^*_{i,t}$, i.e. the effect of changes in X_t working through ripple effects from other regional markets; $x_{j,t}\ \forall j \neq i$.

To find comparable coefficients to the individual areas ECM coefficients, $\beta_{i,y}$, we will compute the *total impact elasticities*, which we will define as the long-run percentage change in $q_{i,t}$ in a situation where all $x_{j,t}$, $\forall j = 0, \ldots, N$ increase by 1%:[15]

$$\beta_{i,x} = \tilde{\beta}_{i,x} + \beta_{i,*}\left(w_i \beta_x\right) \ , \quad \forall i = 0, \ldots, N \tag{17}$$

where w_i is the *i*'th row in w while β_x is a vector of all total impact coefficients; $\beta_{i,x}$, $\forall i = 0, \ldots, N$.[16]

Given that x_t is almost equal for all areas, these so-called *total impact elasticities* are comparable to the standard elasticities of a CVAR model. In the case of the Danish housing markets, most variables are closely correlated across areas, and, hence, we will consider the total impact elasticities when comparing the long-run coefficients of the different models.

4.4 The random coefficients modelling approach (RCM)

By using a RCM approach, we further utilize the cross-sectional variation in the data by restricting the long-run coefficient in the $\mathrm{ECMX}^*{}_i$ models in (10). Specifically, for given β_j-coefficients across areas (e.g. β_{MFY}), we will find $Q = 2$ cross-section (CS) variables; IV_{j1} and IV_{j2}. These will be given by economic theory as variables that should explain a large part of the cross-sectional variation in the β_j-coefficient (see also Anundsen and Heebøll (2013a)). In some cases we will also use CS dummy variables as done using cluster-optimization in Lin and Ng (2012). An example follows below. For a chosen β_j-vector we will impose the following linear restriction:

$$\beta_{j,i} \quad = \quad a_{j0} + a_{j1} IV_{j1,i} + a_{j2} IV_{j2,i} \ , \quad \forall i = 0, \ldots, 13 \tag{18}$$

Here, we find the optimal a_js as the maximum sum of log-likelihoods from all 14 $\mathrm{ECMX}^*{}_i$ models in (10), i.e. profile likelihood optimization.

For example, consider the semi-elasticity coefficient related to MFY, β_{MFY}. Here, we find regional proxies for the number of financially constraint agents in the year just before the ARM and IOM was introduced. In areas where there are more agents that are financially constraint, we should expect a larger semi-elasticity related to MFY. Using these as instruments in the optimization in (18), we make sure that the simi-elasticities,

[15]By this way of calculating the total elasticities we assume that the $x_{i,t}$s are national variables. If that is not the case, one should account for the correlations between the $x_{i,t}$s.

[16]The calculation in (17) is not is not easy to do since each $\beta_{i,x}$ depends on all the other $\beta_{i,x}$s. For this we will simply use a loop, and we find that the calculations do converge to some specific elasticities. Here, we assume it converge "nicely", meaning that this is the "true" total impact elasticities.

cross-sectionally, are measured/restricted as a linear function of the instruments considered. Hereby we use information cross-sectionally.

Given that we restrict $\tilde{P}$ long-run coefficients for $\tilde{N}$ areas – which could be lower then N – these restrictions can be tested using LR-test with $\left(\tilde{N} - Q - 1\right)\tilde{P}$ degrees of freedom. We will also calculate the standard deviation of the a_j's using standard maximum likelihood theory and use these in combination with a formula for the variance of $\beta_{j,i}$ in (18) to calculate measures of the standard deviation on the RCM restricted $\beta_{j,i}$ estimates.[17] Note, however, these are ”quasi” standard deviations, calculated as simple functions of $IV_{j1,i}$, $IV_{j2,i}$ and the standard deviations of the a_js.

4.5 The simulation and bootstrap procedure

To validate the different model specifications and to analyze the effects of the different policy interventions affecting the housing boom of the 2000s, we simulate the housing prices from 2000q1 and onwards. This is done on the basis of the GECM model in (12), for the RCM panel models, after restricting the long-run coefficients using (18). First, as a check of the predicting power of the models and to have a *benchmark* ”real world” scenario, we conduct this simulation based on the actual economic developments of all exogenous variables. Further, to analyze the influence of each individual policy intervention as discussed in Section 2, we carry out similar simulation, but on the basis of counterfactual developments of different exogenous variables – e.g. in the case where the ARMs had not been introduced and the MFY included a fixed long-run interest rate throughout the entire sample period (see Figure 2).

To compare the relative importance of the different policy interventions, we will calculate the difference between the *benchmark* ”real world” simulated price increase during the housing boom (2000q1–2007q1) and the simulated price increase in each of the counterfactual scenarios considered. To measure the uncertainty – as far as the model is concerned – we use a standard non-parametric bootstrap procedure:

1. On the basis of the estimated model in (12), possibly including the RCM restrictions in (18), we randomly rearrange the error-terms within each area and simulate the housing price of each area throughout the entire sample period.
2. On the basis of these simulated prices, we estimate the entire model again and use this estimation to simulate the scenario of interest.

This procedure is repeated for 200 iterations to establish confidence intervals.[18]

[17]We use the standard variance formulas for a sum of K products, where the $\widetilde{IV}_k s$ are considered constants and the $a_k s$ are random variables: $var\left(\sum_{k=1}^{K}\widetilde{IV}_k a_k\right) = \sum_{k,l=1}^{K}\widetilde{IV}_k\widetilde{IV}_l Cov(a_k, a_l)$, where $\widetilde{IV}_k = 1$ for $k = 0$ and $\widetilde{IV}_k = IV_k$ for $k = 1, 2$.

[18]In the current OX program setup, we are limited by lag of memory.

5 The Data

In this section we present the time-series and cross-sectional (CS) data, where the latter is used for the RCM restrictions.

5.1 The times-series data

As shown in the map in Figure 1, the model includes all 14 mainland Danish counties (*amter*), analyzed quarterly from 1987 to 2012.[19] Most variables are based on register data from Statistics Denmark, which allows us to retrieve data at county level, even after 2006 when the county structure was abandoned (see Appendix A). As shown in Table 2, for each area the model includes one endogenous variable, the log real housing price and five fully exogenous variables in accordance with the theoretical motivation in Section 3. We also include the number of families in each region as an exogenous variable affecting only in the short run. This is found to be an important control variable – especially for general urbanization seen through the 2000s. The GVAR models also include the partially exogenous variable given by the restricted 1/distance weighted average of housing prices in other related areas; $p_t^* = w\mathbf{p_t}$ (see the restrictions on w in Table 1).

For data, graphs and further details on data construction see Appendix A, including sources in Table A.1. As seen from the graphs in Figure A.1 in Appendix A, all variables seem non-stationary. Further, many of the exogenous variables are closely correlated across areas, especially the UC and MFY.

5.2 The cross-sectional data

For the four important long-run coefficients in terms of policy implications we impose panel restrictions in line with the RCM approach. These are; *i*) the semi-elasticity on MFY (β_{MFY}), *ii*) the semi-elasticity on UC (β_{UC}), *iii*) the semi-elasticity on unemployment rate (β_u) and *iv*) the elasticity on disposable income (β_y). For each restriction we use two CS variables, either continuous or dummy variables. Later, in the GVAR model, we will also restrict the ripple price effects working through the elasticity on foreign area prices (β_*).

First, as a measure for the effect of financial deregulations – in the model measured by the price semi-elasticity of MFY ($\beta_{i,MFY}$) – we follow the recent literature and utilize the share of first-time buyers with a relatively high loan-to-income ratio (LTI) prior to the financial deregulation being implemented (see e.g. Wheaton and Nechayev (2008) and Anundsen and Heebøll (2013a)). Ideally, we would like to have a measure of the

[19] Here we include Copenhagen and Frederiksberg municipality as one county, but we exclude Bornholm.

Table 2: Times-series variables specification

Endogenous variables	Measurement
Housing prices (p)	Real, log
Exogenous variables	
Housing stock (h)	Living space of owner-occupied houses, log
Standard real user cost (UC)	Property taxes + real fixed interest payments (30 year horizon)*
Minimum first year mortgage yield (MFY)	Property taxes + the currently lowest possible interest and amortization rate (nominal)*
Unemployment rate (u)	Net unemployment rate**
Disposable income (y)	Real, log
Short-run exogenous variables	
Population (fam)	Number of families, log

Note: *) These include property taxes on newly purchased owner-occupied dwellings, including both government property value tax (*ejendomsværdiskat*) and regional specific municipal land tax (*grundskyld*) (see Heebøll et al. (2013) for details) **)) The net unemployment rate excludes people in jobs with government wage subsidies. ***) The short-run exogenous variables are only allowed to affect housing prices in the short run, i.e. through $\sum_{j=0}^{J^x-1} \mathbf{\Upsilon_j \Delta X_{t-j}}$ in (12).

share of housing buyers who would take on a higher mortgage debt-to-payment ratio if they were able to do so – i.e. they are credit constrained.[20] Here, we consider the share of individual new housing buyers with a LTI above 5 compared to the number having a LTI above 2. The latter is done to remove a lot of "noise", observed in the share of new housing buyers with a LTI below 2.[21] Further, the tendencies for people to apply the new mortgage types, may be age dependent. We will therefore as a second CS variable consider the share of people above 30, assuming that people below 30 have lower risk aversion and are more willing to defer amortization given that they typically have a higher expected income compared to their current income.[22] $\beta_{i,UC}$ might also be age dependent, and as CS variables we consider the share of people above 30 and the share of people above 60. These CS variables are shown to the top in Figure 6. As seen, the share of new housing buyers with a high LTI is typically higher in urban areas. That said, some rural areas also have relatively high shares – especially areas near the west cost of Jutland, Ribe and Ringkobing. Also, the share of people below 30 is relatively high in Copenhagen center and Aarhus.

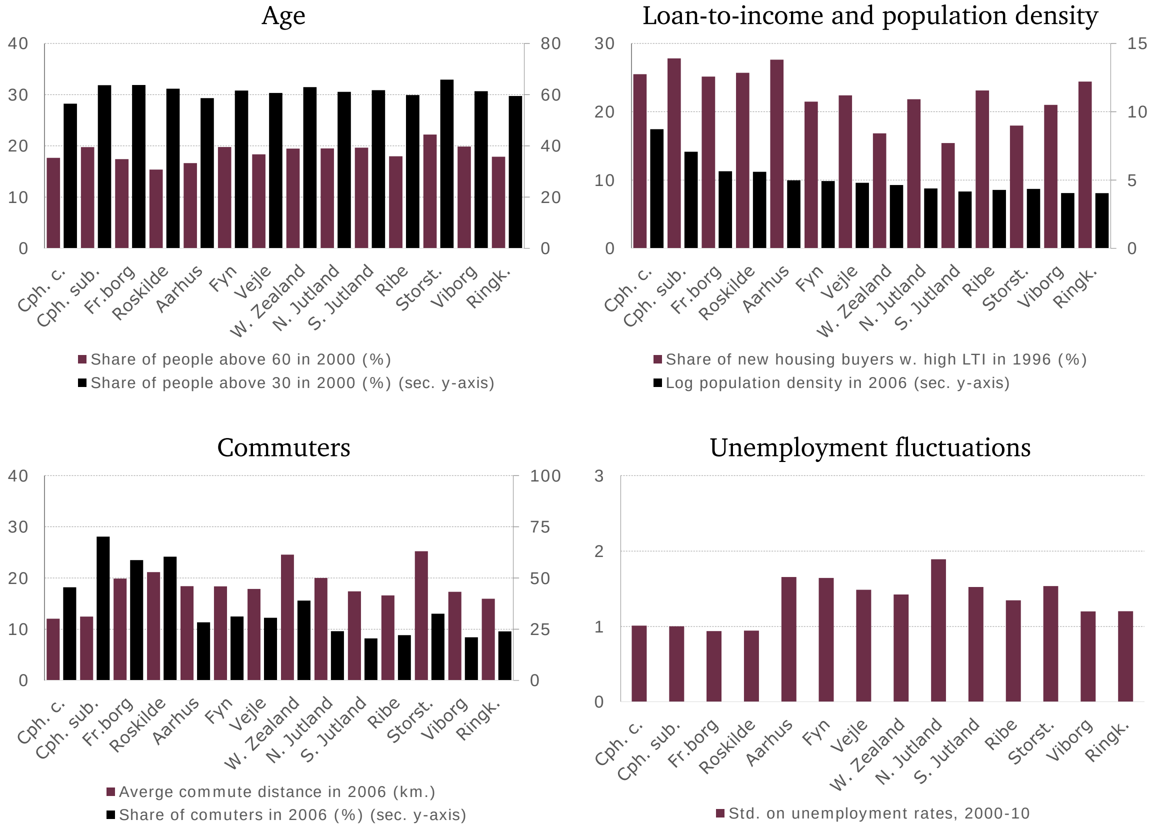
For the unemployment rate (β_u), one should expect a relatively low sensitivity in areas

[20] Analyzing regional US housing and credit markets Huang and Tang (2012), Mian and Sufi (2009) and Anundsen and Heebøll (2013b) also consider the loan denial ratio before the subprime credit boom. Such measures are not – that I know of – available for Danish mortgage credit markets.

[21] Given that we are considering data for individuals, this could reflect that some areas have more singles then other areas. This is something we will have to analyze deeper in order to get a more clean measure.

[22] MFY measures both the effect of IOMs and ARMs. People may prefer IOM because they want to defer amortization and prefer ARM because they want to take on more risk in terms of interest rate fluctuations. This might complicate things. For example, older people who are retiring from work may be more willing to defer amortization, given their lower willingness to save. At the same time they also, typically, have a higher risk aversion. Hence, $\beta_{i,MFY}$ could be both positively and negatively related to the share of older people.

Figure 6: CS-variables used in the RCM panel restrictions



Note: The areas are ordered by population density (highest to the left).

where people are likely to commute and find jobs in other regions. Therefore, we consider the average commute distance pr. worker in the region. Other than that, there may be structural and sectorial differences between the regional labor markets, where some markets are more prone to unemployment rate fluctuations. To control for this we also include the unemployment rate volatility over the period from 2000 to 2010. For the income elasticity (β_y) we do not have any obvious proxies. Instead we will consider a dummy approach as argued for in terms of UK regional housing markets by Ashworth and Parker (1997), depending on whether the area is a bigger city county, rural areas or in between (to be defined later). The proxies for the unemployment rate are shown in the bottom in Figure 6. As seen the unemployment volatility is lower in urban and suburb areas (furthest to the left).

In the end, from the theoretical discussion of price ripple effects in Section 3.2, the elasticity to related market prices (β_*) should, among other things, depend on the degree to which housing services in the given market are substitutes for housing services in related markets. From a labor market point of view, when prices increase in a given region – say central Copenhagen – people will migrate to suburbs where they are still able to commute to work in the center. From this perspective, we include as the first

CS variable, the share of people that commute.[23] Further, as motivated by the results in Vansteenkiste (2007) we also include a simple measure of the land availability for construction – the log population density. The share of commuters are also seen in the bottom in Figure 6. As seen the commute distance deviates a lot from share of commuters, and specially it is high in suburb areas. The log population density in shown in the top in Figure 6.

6 CVAR estimation results

In this section we first estimate the unrestricted regional CVAR models, corresponding to the $ECMX_i^*$-representation in (10) with the coefficients on p^* restricted to zero. Further, we analyze the long-run coefficients cross-sectionally and impose restrictions in line with the RCM approach in (18).

For all 14 regions, we estimate a CVAR model with the variables shown in Table 2. We first test the lag-length of the models using the Akaike information criterion (AIC), as shown in Table B.1 in Appendix B. In most cases the tests indicate a lag-length of either *l=1* or *l=2* (in the models on ECM form). So far, we have restricted the model to a maximum lag-length of *l=2* as seen to the right in the Table B.1 in Appendix B. We generally include an impulse dummy in 1990Q1, where most areas indicate a large outlier. With this specification, the normality assumption is accepted for almost all regions as shown in Table B.1 in Appendix B.

Table B.2 in Appendix B shows the long-run structure of the unrestricted ECM models. From the error-correction coefficients, the prices seem to error-correct in all areas, indicating a rank of *r=1*. Compared to the theoretical predictions of the inverse housing demand equation in (3), few coefficients have unexpected signs and only in one case is it significant (Viborg). Having said this, the results show large differences in the long-run price formation across regions, as well as a lot of "noise" with coefficients being rather extreme and insignificant.

To get a broader picture of the regional market structures we will – in addition to the individual area coefficients – also consider weighted national coefficients as well as three weighted regional indices of; *i*) geographical centers, *ii*) suburbs, and *iii*) rural counties. All are weighted by the share of the total housing supply in year 2000 of the areas in the particular index. The geographical centers are defined as Copenhagen center and suburbs as well as Aarhus. Suburbs include Frederiksborg, Roskilde and Vejle, while

[23]This is defined on a municipality basis, as the share of people that are working in another municipality than where they live. Note, here we do not use the average commute distance, since this includes some other tendencies, namely that areas with a short commute distance to e.g. Copenhagen in that case should be less dependent on ripple price effects – i.e. the opposite than what you would expect.

the rural counties include the rest.[24] For the long-run housing market structures, these are shown in the lower part of Table B.2 in Appendix B. As seen, geographical centers and suburbs are significantly more dependent on MFY. The semi-elasticity on UC are extraordinarily high in suburbs, while geographical centers are relatively more exposed to unemployment rates and supply changes, but less exposed to disposable income.

To analyze these differences cross-sectionally, we further consider the regional income elasticities in more detail in order to define CS dummy variables. As seen, the coefficients are quite similar in all five areas having the lowest population density, along with Vejle. These will be referred to as *periphery counties*. We also see clear similarities in the case of areas surrounding Copenhagen plus areas including a city of between 100,000 and 250.000 citizens – Roskilde, Frederiksborg, West Zealand, Fyn and North Jutland. These will be referred to as *semi-periphery counties*. The maiming areas are the geographical centers. On the basis of these results and interpretations we construct two CS dummy variables for periphery counties and geographical centers.

Table 3: OLS regressions and RCM restrictions on the CVAR β's

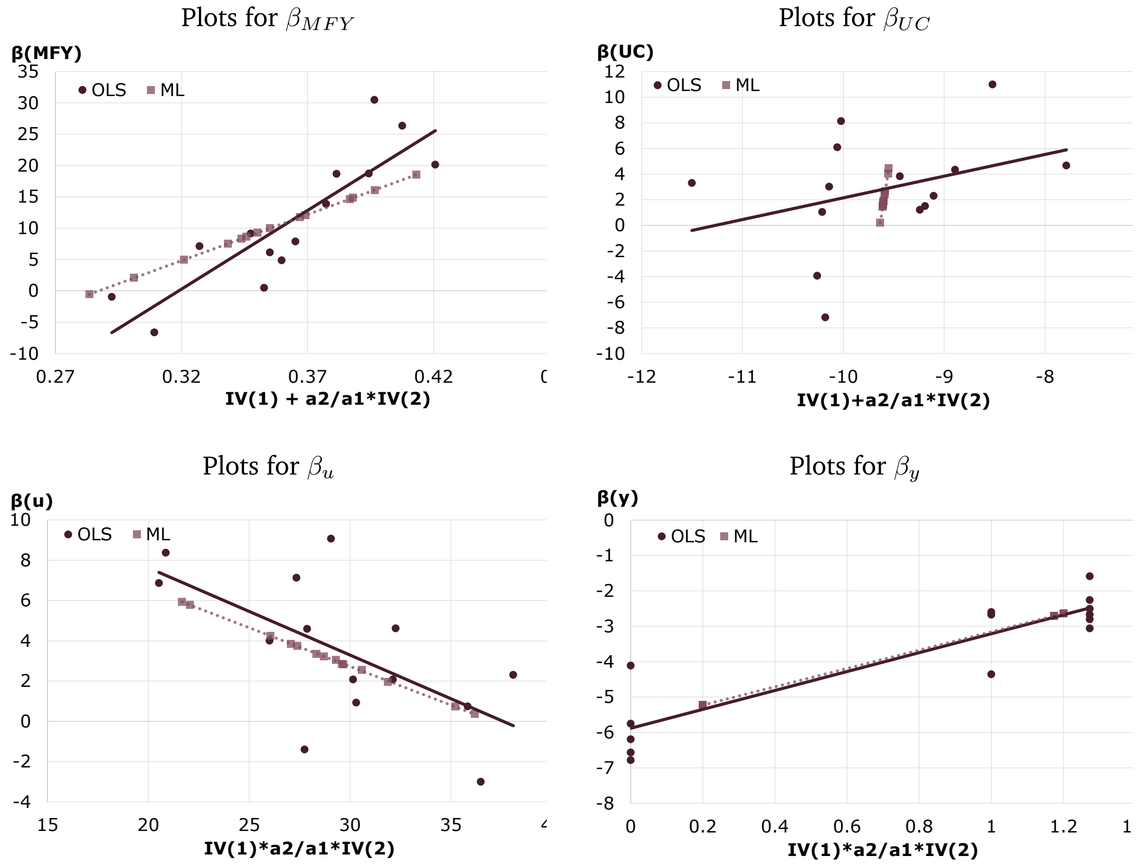
	β_{MFY}		β_{UC}		β_y		β_u	
	OLS	ML	OLS	ML	OLS	ML	OLS	ML
Share of ft.buyers w. high LTI	251.10 (5.56)	147.10 (17.53)						
Share of people above 30	56.26 (0.77)	42.76 (5.06)	1.69 (0.03)	50.27 (0.39)				
Share of people above 60			-92.75 (-1.05)	-56.40 (-1.29)				
Periphery counties (dummy)					3.40 (6.65)	2.52 (4.25)		
Geographical centers (dummy)					2.67 (4.34)	2.59 (2.57)		
Average commute distance							-0.43 (-1.81)	-0.38 (-2.91)
Unemployment rate volatility							-3.63 (-1.21)	-0.98 (-0.56)
Constant	-80.08 (-1.61)	-49.60 (-9.33)	19.09 (0.57)	-18.20 (-0.23)	-80.08 (-1.61)	-49.60 (-9.33)	-5.88 (-15.58)	-5.23 (-9.80)
R^2 / partial p-values* (β_js)	0.79	0.19	0.25	0.04	0.84	0.93	0.49	0.31
Arcumulated p-value**								0.06

Note: The numbers in parentheses are t-values. The partial p-values are LR-tests for the individual β_j CS-restriction restrictions. The accumulated p-value is LR-tests for all CS-restrictions. *) This is a LR-test with 1*(14-3) = 11 degrees of freedom, $\chi^2(11)$. **) This is a LR-test with 4*(14-3) = 44 degrees of freedom, $\chi^2(44)$.

Table 3 shows simple OLS regressions (the OLS-columns) of the β_j-vectors against the relevant CS variables and CS variables given in Figure 6. As indicated by the R^2 in the bottom, all β_j-vectors seem relatively well explained by the proxies. This impression is further reinforced by the regression plots in Figure 7, where the X-axis shows the combined regressor; $IV_{j1,i} + (a_{j2}/a_{j1})IV_{j2,i}$.

[24] This way of dividing into regional indices are partly based on the area characteristics and partly on the the ordering of the size of the housing price boom from 2000 to 2007, divided in to Zealand and Jutland/Fyn. From Figure 1 Copenhagen center and close suburbs saw a significantly higher housing prices boom than the rest of Zealand, while Aarhus saw a significantly higher housing boom then the rest of Jutland/Fyn etc.

Figure 7: OLS regressions and RCM restriction plots on the CVAR



Note: The plots are illustrations of estimation results in Table 3.

Further, we use the RCM approach in (18) to restrict the long-run coefficients cross-sectionally. The a_j-coefficients are shown in the ML-columns in Table 3 along with the t-values. At the bottom of each column we show *partial p-value* of the LR-test of the hypothesis, H_0, that the model explains less when restricting the particular β_j-vector as shown in (18). As seen, none of the restrictions are minimizing the explanatory power significantly. I the bottom right we show the *p-value* of the LR-test of the hypothesis, H_0, that the model explains less when commonly restricting all β_j-vector as shown in (18). This does not significantly minimize the explanatory power either. Table B.3 in Appendix B shows the *p-values* of the individual area restrictions. All individual area restrictions are also accepted. As seen from Table 3 some of the ML coefficients change a lot compared to the OLS coefficients, and the *partial p-values* for the individual β_j-vectors do not follow the OLS R^2 in all cases. This is due to the fact that the OLS regressions do not account for the significance of each particular $\beta_{j,i}$.

Considering the individual CS-coefficients, the semi-elasticity on MFY, β_{MFY}, is found to be positively related to the share of buyers with a high LTI. This indicates – as found previously by Wheaton and Nechayev (2008) and Anundsen and Heebøll (2013b) – that this is a relevant proxy for the regional share of credit rationed housing buyers and, hence, the effects of financial deregulation. As seen from the patterns in Figure 6, this also indicates that MFY has a larger influence in larger city areas. A bit unexpected, we find that the share of people above 30 is positively related to the semi-elasticity on MFY. The semi-elasticity on UC, β_{UC}, is not significantly related to either the share of people above 30 or 60. This indicates that β_{UC} is not significantly different across areas given these proxies.

With regards to β_u we find, as expected, that prices in areas with a high average commute distance pr. worker are less sensitive to the regional unemployment rate. The semi-elasticity is negatively related to the unemployment rate volatility, but not significantly so. For the income elasticities we find, as discussed above, that housing prices in semi-periphery counties are significantly more exposed to income changes.[25]

Further, the resulting long-run estimates of the restricted CVAR are displayed in Table B.3 in Appendix B. Here, the significance of the coefficients has increased, and they generally show fewer outliers compared to the unrestricted CVAR coefficients. Only in one case does a coefficient have an unexpected sign (again Viborg). Hence, by using the panel information it seems we have reached a more accurate estimation of the regional specific housing market structures and (as will be analyzed later) the effects of policy interventions. However, considering the aggregated coefficients at the bottom of the table, the RCM restrictions have changed the regional market structure to some extent. The semi-elasticities on MFY have decreased in geographical centers and suburbs and increased in rural areas, while the semi-elasticities on UC have decreased in geographical centers. The remaining coefficients only show minor changes.

7 GVAR estimation results

In this section we start by estimating the unrestricted $ECMX_i^*$ in (10) including p^*. We still include an impulse dummy in 1990Q1. The test for lag-length and normality of the error terms etc. are shown in Appendix C. We still (at the moment) use a maximum lag-length of $l = 2$ in the model on ECM form. The chosen lag-lengths are shown to the right in the table.

The long-run coefficients of the unrestricted model can be seen in Table C.2 in Appendix C. All coefficients seem to change a lot compared to the unrestricted CVAR model. However, all time series variables are also closely correlated across areas (see Figure A.1 in Appendix A). In fact, the UC and MFY could almost be considered national variables. When interpreting these β-estimates as partial elasticities, this result is not that surprising (see Section 4.3). Therefore, in Table C.3 in Appendix C we have calculated the *total impact* $\tilde{\beta}$-estimates, following (17). At least for β_{MFY} and $\widetilde{\beta}_y$ these are much more in

[25]Note that $\beta_{i,y} < 0$, $\forall$ i $= 0, \ldots, 13$.

line with the unrestricted estimates of the CVAR model, as well as economic theory. The $\widetilde{\beta}_u$s are quite high compared to the CVAR estimates, which may reflect that these are not as correlated across areas as $\widetilde{\beta}_{\mathrm{MFY}}$ and $\widetilde{\beta}_{\mathrm{y}}$. The $\widetilde{\beta}_{\mathrm{UC}}$s are found to be negative in almost all areas, possibly as a result of the high correlation between UC and MFY. Considering the weighted regional total elasticities in the bottom, we notice especially that $\widetilde{\beta}_{MFY}$ is more equal across areas compared β_{MFY}. This indicates that the direct price effects of financial deregulation were much bigger in geographical centers and to some extend suburbs, while the rural areas where typically affected through the price ripple.

Table 4 further shows the cross-sectional OLS regressions of the βs – now including β_* – against the same CS dummies and the CS variables as shown in Figure 6. These are also plotted in Figure 8. As seen from the R^2s, all β_j-vectors are still relatively well explained by the CS variables, but not as well as found in the case of the CVAR models. Further, we restrict the GVAR β_j-vectors cross-sectionally as done for the CVAR models (see (18)). The CS coefficients are shown in the ML-columns in Table 4 . However, here we find that, given the interconnectedness of all areas, it is problematic – if not impossible – to restrict all areas at the same time. Therefore, will see Copenhagen center as a reference area which will not be directly restricted by the RCM approach.[26] As seen from Table 4, we are able to accept all partial restrictions, while the combined restrictions on all 13 β_j-vectors are borderline accepted/rejected with a *p-value* of 0.04. The *p-values* of the individual area restrictions are shown to the right in Table C.4 in Appendix C. Here, we see that the low *p-value* of the combined restrictions has to do with the restriction on Vejle. With this in mind we are still going to keep the combined restrictions on the 13 models.

Considering the ML-regressors in Table 4, we see that price ripple effects are significantly larger in areas of higher population density and in areas where people tend to commute.[27] The first result is in line with Vansteenkiste (2007) while the latter may indicate that when prices increase in the e.g. Copenhagen center, people move to areas where they can still commute to their work in the center. However, this result could also be partly due to our definition of p^* as the distance weighted average of housing prices in other areas, with the restrictions given in Table 1. In particular, if the housing boom of the 2000s started spreading through ripple price effects from Copenhagen – as seems to be the case – areas that are close to Copenhagen where people are more likely to commute will – given the model structure – possibly react more directly to the ripple through p^*.

Comparing the ML-regressors in Table 4 with the ones for the CVAR model in Table 3, we see some significant changes in the other coefficients. Specifically, β_{MFY} is still positively related to the share of new housing buyers with a high LTI but not significantly so. The

[26]The coefficients for Copenhagen center are indirectly restricted/affected by the restrictions on all other areas through the ripple effects.

[27]Note that $\beta_{\mathrm{i},*} < 0, \forall\ \mathrm{i} = 0, \ldots, 13$.

Table 4: OLS regressions and RCM restrictions on the GVAR β's

	β_*		β_{MFY}		β_{UC}		β_y		β_u	
	OLS	ML	OLS	ML	OLS	ML	OLS	ML	OLS	ML
Share of ft.buyers w. high LTI			16.25 (0.79)	15.54 (0.67)						
Share of people above 30			−69.37 (−2.08)	−29.26 (−0.34)	−48.50 (−2.68)	−58.26 (−2.45)				
Share of people above 60					−5.12 (−0.20)	−38.78 (−1.09)				
Periphery counties (dummy)							0.90 (1.20)	1.52 (2.94)		
Geographical centers (dummy)							0.38 (0.61)	0.94 (2.25)		
Average commute distance									−0.45 (−2.69)	−0.30 (−7.27)
Unemployment rate volatility									4.24 (2.04)	5.00 (4.33)
Share of commuters	−1.19 (−3.59)	−2.82 (−14.79)								
Log population density	0.09 (2.31)	0.41 (25.64)								
Constant	−0.72 (−4.60)	−1.68 (−17.68)	41.90 (1.86)	17.01 (0.30)	30.03 (3.14)	42.63 (3.49)	−1.63 (−3.55)	−1.08 (−0.58)	3.25 (0.97)	−1.08 (−0.58)
R^2 / partial p-values* (β_j)	0.61	0.46	0.49	0.10	0.57	0.43	0.25	0.14	0.52	0.50
Arcumulated p-value**										0.04

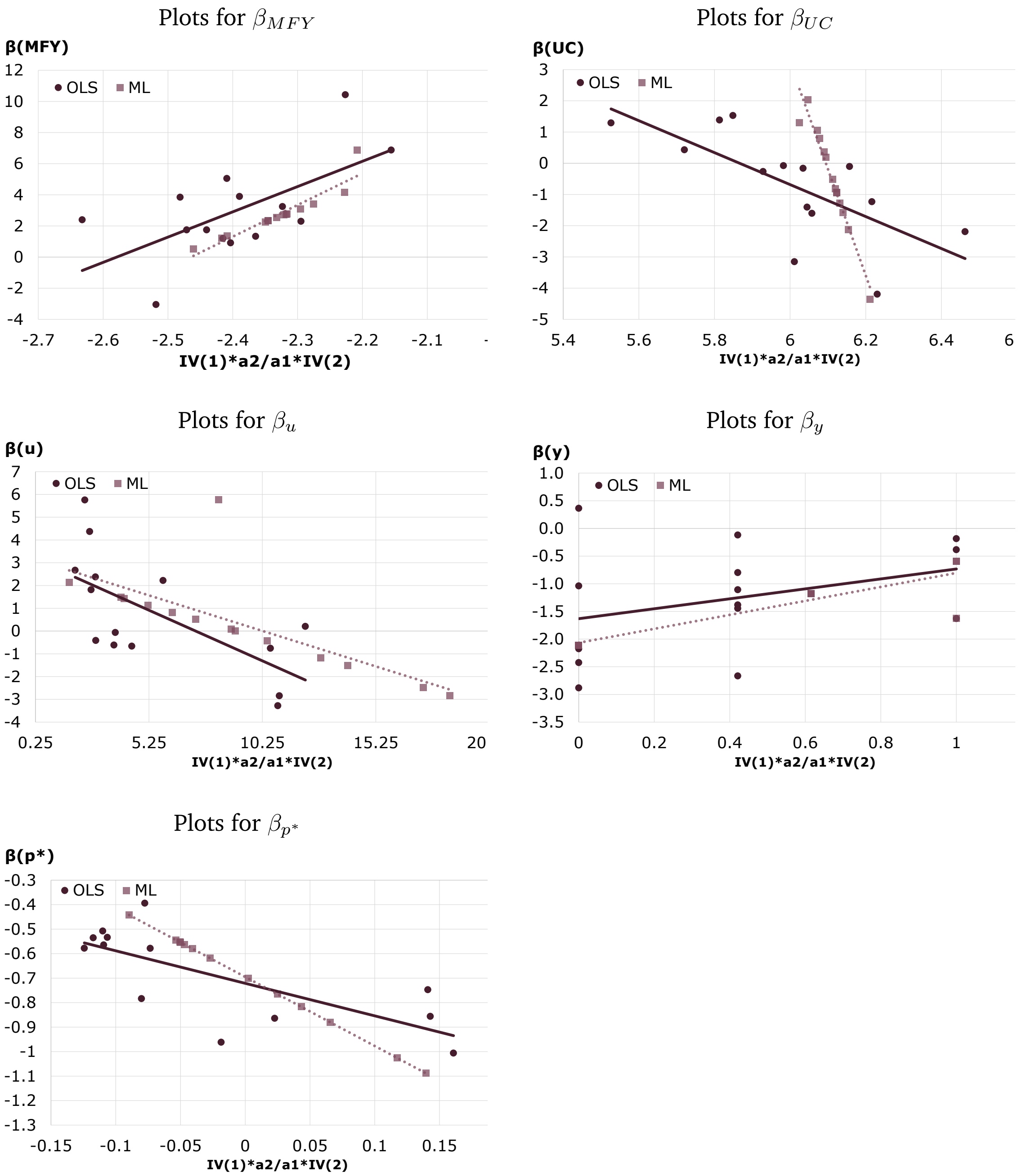
Note: The numbers in parentheses are t-values. The partial p-values are LR-tests for the individual β_j CS-restriction restrictions. The accumulated p-value is LR-tests for all CS-restrictions. *) This is a LR-test with 1*(13-3) = 10 degrees of freedom, $\chi^2(10)$. **) This is a LR-test with 5*(13-3) = 50 degrees of freedom, $\chi^2(50)$.

β_{UC} is negatively related to the share of people above 30 and more so for the share of people above 60. Unexpectedly, we now find that the semi-elasticity on unemployment rate is positively related to unemployment fluctuations. Generally, it seems that the introduction of p^*, meaning that we are considering partial elasticities $\widetilde{\beta}$s, makes the CS results less clear.[28]

With these restrictions on the GVAR model, Table C.4 in Appendix C shows the long-run coefficient, while Table C.5 shows the total impact elasticities. Now, we see that, except for $\widetilde{\beta}_{\mathrm{UC}}$, all total elasticity coefficients have the expected signs. Also the t-values of the partial elasticities are generally higher. Hence, also in the GVAR model, it seems that by using the panel data dimension, we have significantly increased the precision of the model. That said, again, the RCM restrictions have changed the coefficients quite a bit. The total elasticities on MFY in particular have increased in suburbs and rural counties, again suggesting that these areas are indirectly exposed to the introduction of the new mortgage types through the ripple effect in the GVAR.

[28] We have also tried to restrict the model on the basis of the total elasticities. However, this is problematic as long as all areas are affected by ripple effects. If we used a true triangular structure in the w-matrix, the $\tilde{\beta}$ in (17) can be calculated recursively. Other than that, from a theoretical point of view, the CS variables should be able explain the partial elasticities and not the total elasticities. That is, they should explain the direct area specific effect of a particular variable.

Figure 8: OLS regressions and RCM restriction plots on the GVAR βs



Note: The plots are illustrations of estimation results in Table 4.

8 Simulations and regional effects of policy interventions

Having estimated the four different time-series housing models (CVAR, panel CVAR, GVAR, and panel GVAR), we further simulated the models under different scenarios. First, we simulate the four models in the actual scenario to analyze the predictive power of each of them in turn. In general, we will show the results of the aggregated areas in the text, while the results of the individual areas models are shown in Appendix E.

Further, we simulate each of the models in the different counterfactual scenarios; *i*) if each of the two new mortgage types had not been introduced (analyzed separately), *ii)* if the Danish monetary and fiscal policy had followed a Taylor rule and output-gap rule, respectively, both related to Danish economic conditions (analyzed separately), *iii*) if the property tax had not been fixed nominally in 2002.[29] The calculations of counterfactual scenarios are described in Appendix D.

8.1 The actual scenario (explanatory power)

Table 5 shows the actual historical and actual-simulated real price increase of the four different price indices for each of estimated models from 2000Q1 to 2007Q1. For the individual areas, these results are shown in Appendix E.1 Table E.1 while the related price graphs are shown in Figure E.1.

Table 5: Prices increase in the actual scenario (explanatory power, 2000-07)

	Unrestricted model				Restricted model			
	Geo. centers	Suburbs	Rural areas	National	Geo. centers	Suburbs	Rural areas	National
Act. price increase (%)	106.9	83.4	44.0	70.5	106.9	83.4	44.0	70.5
CVAR								
Sim. price increase (%)	77.4	61.4	37.9	54.8	83.2	57.3	36.2	54.9
	(1.6)	(1.3)	(0.7)	(0.6)	(1.4)	(1.4)	(0.6)	(0.6)
Abs. deviation (pp.)	-29.56	-21.99	-6.10	-15.69	-23.80	-26.10	-7.80	-15.60
Explanatory power (%)	72.37	73.63	86.14	77.75	77.76	68.71	82.27	77.87
GVAR								
Sim. price increase (%)	87.6	69.0	39.8	60.1	86.1	68.4	39.4	59.4
	(1.5)	(1.3)	(0.7)	(0.8)	(1.5)	(1.6)	(0.7)	(0.9)
Abs. deviation (pp.)	-19.40	-14.40	-4.20	-10.40	-20.90	-15.00	-4.60	-11.10
Explanatory power (%)	81.87	82.73	90.45	85.25	80.47	82.01	89.55	84.26

Note: pp. are percentage points. Values in parentheses are standard errors calculated using bootstrap simulations of 200 replications. *Abs. deviations* are defined as *Sim. price increase* minus *Act. price increase*. *Explanatory power* is defined as (*Act. price increase - Abs. deviations*)/*Act. price increase*.

As seen, the models are capable of explaining large shares of both the regional and national Danish price boom in the 2000s – between 77.8 and 85.3% when considering the national indices, and between 68.7 and 90.4% when considering the regional aggregated indices.

Generally, we should expect that the restricted models explain significantly less than the unrestricted model. Here the panel models are restricted versions of the models with

[29] With the nominal property tax freeze from 2002 the property taxes are negatively dependent on housing prices. With the exception of the analysis of the effects of the property tax freeze itself, the counterfactual scenarios resulting in other price developments will in principle also affect the UC and MFY through a different evolution of the property taxes, *ceteris paribus*. This we do not account for, but, if we did, it would not change the results significantly.

out panel restriction, and the standard regional CVAR models are restricted versions of the GVAR models (restricting the influence of p^*). This clearly holds in the case of the influence of p^* in the GVAR model, while the panel restrictions only seem to lower the explanatory power marginally. The last result is due to the fact that we only allow for panel restrictions that are accepted (*borderline*) in the data, i.e. the panel restrictions do not minimize the explanatory power significantly. Going from the GVAR models to the CVAR model we restrict p^*. This we do not test, and, if we did, the restrictions would surely have been rejected (refer to the t-values of the β^*s in Table C.2 and C.4 in Appendix C). Considering the individual area results in Table E.1 in Appendix E.1, the panel restrictions do matter for the precision of the GVAR model, as seen from the standard errors of the simulation results.

Further considering the regional tendencies, the restricted GVAR model is able to explain 80.4% of the housing boom in the geographical centers and 89.5% of the boom in rural areas. This is general to all the models, that they tend to be better at predicting the housing prices booms in rural areas compared to suburbs and geographical centers. The rural areas and suburbs seem to follow the geographical centers. This may indicate that the reason why the model is not able to fully explain the housing boom is to be found in the price formation of the geographical center.

There may be several reasons why the geographical centers are somewhat different from the other areas. One possible explanation is the weight matrix, which is more restrictive in the case of geographical centers. However, if this is the case the explanatory power of geographical centers and rural areas should not differ much in the CVAR model, where we do not account for price ripple effects at all. Here, the explanatory power in rural areas is also significantly higher.

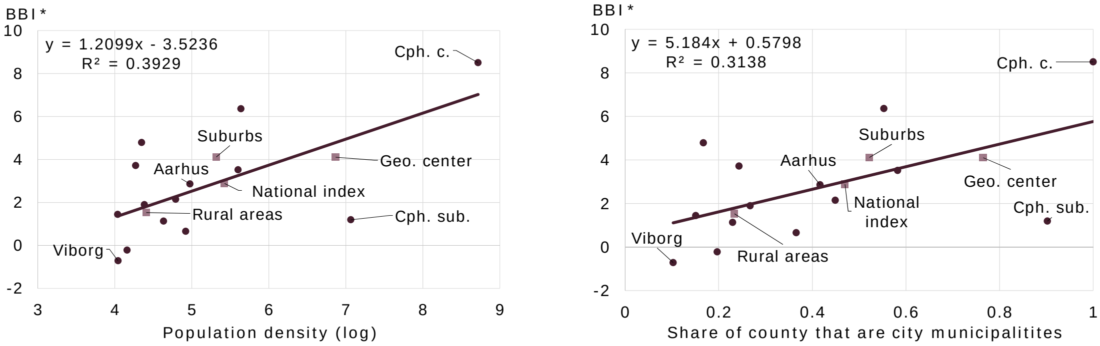
Another possibility is that geographical centers are more affected by adaptive price expectations. As found in Anundsen and Heebøll (2013b), following a housing demand shock, areas with higher restrictions on housing construction – such as as urban areas – typically absorb the shock through price changes instead of supply changes. Hereby the price dynamics in urban areas will be more persistent, which may also result in the expectations being more adaptive. To analyze whether this is the case, we will consider the so called *bubble builder indicator*, defined as the tendency for adaptive expectations given by the short run coefficient on lagged housing prices increases (here including foreign area prices) divided by the tendency for prices to reach to the long-run price formation; $BBI_i = \left(\sum_{j=1}^{J^p} \Gamma^*_{i,j} + \Gamma_{i,j}\right)/\alpha_i$. For further discussions on this index, see Anundsen and Heebøll (2013a) and Abraham and Hendershott (1996). In Figure 9 below we have plotted the BBI for all areas using the restricted GVAR results against the log population density and the weighted share of the county that consist of city municipalities.[30] As seen, prices are significantly more exposed to bubble tendencies in areas

[30] The share of the county that consist of city municipalities (weighted average) are defined as 0.5 times the share of municipalities with more than 1000 people pr. km^2 + 0.5 time the share of municipalities with

that are more densely populated, i.e. geographical center and to some extent suburbs.

Figure 9: BBI plotted against measures of supply restrictions

BBI plotted against log population density | BBI plotted against share of city municipalities



Note: The share of municipalities in the county that are cities (weighted average) are defined as 0.5 times the share of municipalities with more than 1000 people pr. km^2 + 0.5 time the share of municipalities with more then 100 people pr. km^2.

In the end, there might also be an important effect of urbanization which is not adequately modeled. In Copenhagen center the average yearly population growth (number of families) changed from 0.3% in the period from 1997 to 2005 to 1.3% in the period from 2005 to 2012. Considering the same periods, the population growth in Aarhus changed from 0.5% to 1% (see also Figure A.1 in Appendix A). In the model we have tried to account for these urbanization tendencies by including the changes in number of families in the region. However, the population growth may also have some medium or long-run effects on housing prices.

With this in mind we will further consider the effects of the different policy interventions as discussed in Section 2.

8.2 The effects of financial deregulation

To analyze the effect of financial deregulation we consider the counterfactual scenarios in the cases where the ARMs and IOMs had not been introduced as discussed in Section 2.1. For further details regarding the counterfactual calculations, see Appendix D. Table 6 and 7 show the differences between the simulated real price increase in the actual scenario (hereafter the actual-simulated scenario) and price increase in the two counterfactual scenarios – without the introduction of each of the two new mortgages types.[31] The price graphs and individual area results are shown in Figure E.2 – E.3 and Table E.2 – E.3 in Appendix E.2.

more then 100 people pr. km^2 i year 2000. If we did not use a weighted index several counties would have a 0 or 1. Here, the index is 1 for central Copenhagen

[31] In the actual-simulated scenario we consider the model simulations in Table 5.

Table 6: Price increases in the CF scenario without ARMs (2000-07)

	Unrestricted model				Restricted model			
	Geo. centers	Suburbs	Rural areas	National	Geo. centers	Suburbs	Rural areas	National
CVAR simulations								
Act. sim. price increase (%)	83	60	36	55	83	57	36	55
CF. sim. price increase (%)	40	28	31	34	46	36	27	35
	(4.9)	(2.9)	(1.4)	(1.8)	(4.2)	(2.9)	(1.4)	(1.7)
Abs. deviation (pp.)	−43	−32	−6	−22	−37	−22	−9	−20
	(3.0)	(3.0)	(1.2)	(1.8)	(4.6)	(3.2)	(1.3)	(1.7)
Relative deviation (%)	−52	−54	−15	−40	−45	−38	−25	−37
	(5.7)	(5.1)	(3.3)	(3.2)	(5.2)	(5.5)	(3.5)	(3.1)
GVAR simulations								
Act. sim. price increase (%)	88	69	40	60	86	68	39	59
CF. sim. price increase (%)	51	41	22	35	59	43	24	39
	(10.4)	(7.1)	(4.4)	(6.5)	(7.8)	(5.2)	(2.9)	(4.4)
Abs. deviation (pp.)	−36	−28	−18	−25	−27	−26	−15	−20
	(8.5)	(6.0)	(3.9)	(5.5)	(7.1)	(4.6)	(2.8)	(4.1)
Relative deviation (%)	−41	−40	−45	−42	−31	−38	−38	−34
	(9.0)	(8.0)	(8.4)	(8.3)	(7.3)	(6.3)	(5.8)	(6.1)

Note: Prices are simulated based on the CF scenario where the MFY includes a long 30-year mortgage rate throughout the sample, i.e. as if the ARM was never introduced (simulated from 2000q1 to 2007q1) (see Appendix D for details). Numbers in parentheses are standard errors calculated based on bootstrap simulation with 200 replications. The *Abs. deviations* are defined as *CF. sim. price increase* minus *Act. sim. price increase*. *Relative deviations* are defined as *CF. sim. price increase* divided by *Act. sim. price increase* - 1.

Table 7: Price increases in the CF scenario without IOMs (2000-07)

	Unrestricted model				Restricted model			
	Geo. centers	Suburbs	Rural areas	National	Geo. centers	Suburbs	Rural areas	National
CVAR simulations								
Act. sim. price increase (%)	83	60	36	55	83	57	36	55
CF. sim. price increase (%)	42	28	30	34	46	34	26	34
	(5.1)	(3.2)	(1.9)	(2.0)	(4.1)	(4.0)	(1.8)	(1.7)
Abs. deviation (pp.)	−42	−32	−6	−22	−37	−24	−10	−21
	(3.1)	(3.1)	(1.7)	(1.8)	(4.4)	(4.3)	(1.6)	(1.6)
Relative deviation (%)	−50	−53	−17	−40	−44	−41	−29	−38
	(5.7)	(5.4)	(4.6)	(3.4)	(5.0)	(7.5)	(4.6)	(3.1)
GVAR simulations								
Act. sim. price increase (%)	88	69	40	60	86	68	39	59
CF. sim. price increase (%)	39	35	19	28	52	40	23	35
	(7.8)	(5.1)	(3.2)	(4.6)	(7.1)	(4.0)	(2.2)	(3.6)
Abs. deviation (pp.)	−48	−34	−21	−32	−34	−28	−17	−24
	(7.0)	(4.6)	(2.9)	(4.2)	(6.9)	(3.9)	(2.4)	(3.5)
Relative deviation (%)	−55	−49	−53	−53	−40	−41	−42	−41
	(7.5)	(6.1)	(6.3)	(6.3)	(7.1)	(5.0)	(4.8)	(5.1)

Note: Prices are simulated based on the CF scenario where the MFY includes the amortizations on a 30-year annuity throughout the sample, i.e. as if the IOMs were never introduced (simulated from 2000q1 to 2007q1) (see Appendix D for details). Numbers in parentheses are standard errors calculated based on bootstrap simulation with 200 replications. The *Abs. deviations* are defined as *CF. sim. price increase* minus *Act. sim. price increase*. *Relative deviations* are defined as *CF. sim. price increase* divided by *Act. sim. price increase* - 1.

Comparing with the actual-simulated price evolution from Table 5, we see that the national price increase would have been significantly lower from 2000 to 2007 if either one of the mortgage types had not been introduced. For the CVAR models, within the different areas, the total price effect of ARM are almost the same as the effect of IOM. This is due to the fact that in 2007 the MFY would have been about 2 pp. lower in the counterfactual scenario no matter which of the two mortgage types we consider. There are differences in the timing and persistence of the effects on MFY, where the effect of IOMs is relatively constant over time and comes some years after the effect of ARMs (see Figure 2 in Section 2.1). This difference in the timing and persistency is the primary reason why we see a bigger effect of IOMs in the GVAR models.

Regarding the regional simulations, we see that the absolute effects of ARMs and IOMs in the CVAR models seem to be larger in geographical centers, slightly smaller in suburbs and smallest in rural areas. These results change when we consider the GVAR model. Here the relative effects of ARMs and IOMs are almost the same across areas. Along with the results from the previous section, this indicates quite clearly that the direct price effects of the IOM and ARM are largest in geographical centers and suburbs, from which the effects are strongly transmitted to the rural areas through the ripple.

8.3 The effects of fiscal and monetary policy

To analyze the effect of monetary and fiscal policy we utilize the counterfactual scenarios discussed in Section 2.2. For the former we consider a scenario where the monetary policy in Denmark is conducted in accordance with ECB's Taylor rule for the euro area but applied to Danish economic conditions. For the latter we consider a scenario where the fiscal policy follows the output-gap stabilizing fiscal policy rule of Linaa et al. (2008). These scenarios are calculated in Heebøll (2014) and Kraka (2012), and the resulting evolutions of the policy rate and national GDP are shown in Figure 3 in Section 2.2.

Complicating these analyses a bit, the policy rate and real national GDP do not enter the regional housing models estimated in this paper explicitly. However, had the policy rate of the ECB and the Danish Central bank been higher during the 2000s, we would expect this to have resulted in a higher UC and MFY. In the same vein, national developments in real GDP should also affect regional disposable income and unemployment rates. To find counterfactual evolutions in the case of monetary policy, we estimate two ECM models - one for the long and one for the short nominal mortgage rate. Both models are estimated from 2000 to 2012, including the policy rate as an exogenous variable – seen as exogenously given by the ECB. From these models, we simulate the evolutions in the short and long nominal mortgage rates given that the policy rate had followed the Taylor rule for ECB, applied to full-information (no real time) on Danish output-gap and inflations figures from 2004 to 2007.[32] From these results, we calculated counterfactual evolutions in UC and MFY for all areas. For estimation results, calculations, and counterfactual evolutions, see Appendix D.

To find the counterfactual evolution of regional unemployment rates and disposable income, we estimate an ECM model for each variable in each region. In all cases, models are estimated from 2000 to 2012 and we include the national GDP as an exogenous variable – given at a national level. From these models, we simulate the regional unemployment rates and disposable income in the counterfactual scenario, where fiscal policy followed the output-gap stabilizing fiscal policy rule of Linaa et al. (2008). The resulting counterfactual evolutions for selected areas are shown in Appendix D.

Table 8: Price increases in the CF scenario with a "neutral" monetary policy (2000-07)

	Unrestricted model				Restricted model			
	Geo. centers	Suburbs	Rural areas	National	Geo. centers	Suburbs	Rural areas	National
CVAR simulations								
Act. sim. price increase (%)	83	60	36	55	83	57	36	55
CF. sim. price increase (%)	43 (3.7)	28 (2.4)	27 (1.3)	32 (1.4)	47 (3.0)	31 (2.6)	25 (1.3)	33 (1.1)
Abs. deviation (pp.)	−40 (2.6)	−32 (2.6)	−9 (1.2)	−23 (1.4)	−36 (3.7)	−26 (3.1)	−12 (1.1)	−22 (1.2)
Relative deviation (%)	−49 (4.4)	−54 (4.3)	−26 (3.2)	−42 (2.5)	−44 (4.0)	−45 (5.1)	−32 (3.1)	−40 (2.1)
GVAR simulations								
Act. sim. price increase (%)	88	69	40	60	86	68	39	59
CF. sim. price increase (%)	51 (5.8)	46 (4.1)	25 (2.4)	37 (3.5)	58 (5.3)	47 (3.2)	28 (1.6)	41 (2.7)
Abs. deviation (pp.)	−37 (5.5)	−23 (3.9)	−15 (2.2)	−23 (3.3)	−28 (5.3)	−21 (3.2)	−12 (1.7)	−18 (2.7)
Relative deviation (%)	−42 (5.8)	−33 (5.1)	−37 (4.8)	−38 (4.9)	−32 (5.5)	−31 (4.2)	−30 (3.5)	−31 (3.9)

Note: Prices are simulated based on the CF scenario where the monetary policy followed the ECB Taylor-rule applied to Danish conditions from 2004-07, affecting MFY and UC in the models (simulated from 2000q1 to 2007q1) (see Appendix D for details). Numbers in parentheses are standard errors calculated based on bootstrap simulation with 200 replications. The *Abs. deviations* are defined as *CF. sim. price increase* minus *Act. sim. price increase*. *Relative deviations* are defined as *CF. sim. price increase* divided by *Act. sim. price increase* - 1.

[32] Full-information means that the counterfactual scenario is based on the revised figures for inflation and output-gap (no real time figures). Since we are not interested in analyzing the policy rule as such, we find that the full-information scenario is the most appropriate case to consider.

Table 9: Price increases in the CF scenario with a "neutral" fiscal policy (2000-07)

	Unrestricted model				Restricted model			
	Geo. centers	Suburbs	Rural areas	National	Geo. centers	Suburbs	Rural areas	National
CVAR simulations								
Act. sim. price increase (%)	83	60	36	55	83	57	36	55
CF. sim. price increase (%)	71 (2.1)	47 (1.7)	27 (0.9)	45 (0.8)	72 (1.4)	45 (1.9)	27 (0.7)	44 (0.7)
Abs. deviation (pp.)	−12 (0.8)	−13 (0.8)	−9 (0.5)	−11 (0.5)	−11 (1.2)	−12 (0.6)	−9 (0.3)	−11 (0.4)
Relative deviation (%)	−15 (1.6)	−22 (1.7)	−26 (1.4)	−20 (0.9)	−14 (1.3)	−22 (1.6)	−25 (1.0)	−19 (0.8)
GVAR simulations								
Act. sim. price increase (%)	88	69	40	60	86	68	39	59
CF. sim. price increase (%)	71 (2.1)	54 (1.4)	29 (0.7)	47 (1.0)	71 (1.6)	54 (1.3)	29 (0.6)	47 (0.8)
Abs. deviation (pp.)	−16 (1.4)	−15 (0.9)	−11 (0.5)	−13 (0.8)	−16 (1.4)	−15 (1.0)	−10 (0.5)	−13 (0.8)
Relative deviation (%)	−19 (1.6)	−22 (1.2)	−26 (1.1)	−22 (1.2)	−18 (1.4)	−22 (1.1)	−27 (1.0)	−22 (1.1)

Note: Prices are simulated based on the CF scenario where the fiscal policy (u and y in the models) followed an output-gap stabilizing rule from 2004-07 (simulated from 2000q1 to 2007q1) (see Appendix D for details). Numbers in parentheses are standard errors calculated based on bootstrap simulation with 200 replications. The *Abs. deviations* are defined as *CF. sim. price increase* minus *Act. sim. price increase*. *Relative deviations* are defined as *CF. sim. price increase* divided by *Act. sim. price increase* - 1.

Given these estimations and calculations, Tables 8 and 9 show the differences between the actual-simulated and counterfactual simulated real price increases in the two scenarios – with a "neutral" monetary and fiscal policy, both implemented from 2004 to 2007. The related price graphs and individual areas' price increases are shown in Figure E.2 – E.3 and Table E.4 – E.5 in Appendix E.3.

On the national scale, the effect of the expansionary monetary policy of the 2000s is found to be larger than the effect of fiscal policy. However, when considering the regional effect we generally see a larger effect from expansionary monetary policy in geographical centers, while the effect of fiscal policy is larger in rural areas. Hence, the general tendency is that urban areas are more sensitive to changes in financial conditions. In fact, the large effect of monetary policy may party be due to the financial deregulation and introduction of new mortgage types. To explore this hypothesis, Table 10 shows the simulated price increase in combined counterfactual scenarios (only for the panel restricted models). That is the scenarios with a "neutral" monetary policy, and given that IOM or ARM were not introduced. Comparing the right column of Tables 8 with the two columns in Table 10 it seems that the effect of monetary policy has increase following the introduction of both IOM and ARM. However, the effect of ARM seem to have increased the interest rate sensitivity the most. These results are in line with results in Heebøll (2014).

This suggest some other interesting results: during times of expansionary monetary policy set by the ECB, a national output-gap stabilizing fiscal policy may not be sufficient to stabilize the housing market. That is, not after the introduction of ARM and IOM and especially not in urban areas.

Table 10: The price effect of a ”neutral” monetary policy without IOM or ARM (2000-07)

	Without ARM				Without IOM			
	Geo. centers	Suburbs	Rural areas	National	Geo. centers	Suburbs	Rural areas	National
Restricted CVAR simulations								
CF.sim.price increase without ARM/IOM (%)	46	36	27	35	46	34	26	34
CF.sim.price increase without ARM/IOM and with a ”neutral” monetary policy (%)	28	20	19	22	17	12	15	15
Abs.deviation and effect of monetary policy (pp.)	-18	-15	-8	-13	-29	-22	-11	-19
Restricted GVAR simulations								
CF.sim.price increase without ARM/IOM (%)	59	43	24	39	52	40	23	35
CF.sim.price increase without ARM/IOM and with a ”neutral” monetary policy (%)	45	33	19	30	29	23	12	20
Abs.deviation and effect of monetary policy (pp.)	-14	-10	-6	-9	-23	-18	-10	-16

Note: Prices are simulated based on the CF scenario where the monetary policy followed the ECB Taylor-rule applied to Danish conditions from 2004-07, affecting MFY and UC in the models (simulated from 2000q1 to 2007q1) (see Appendix D for details). *Abs.deviation and effect of monetary policy* is given as *CF.sim.price increase without ARM/IOM and with a ”neutral” monetary policy* minus *CF.sim.price increase without ARM/IOM*.

8.4 The effects of the property tax freeze

Finally, Table 11 shows the effects of the property tax freeze from 2002 and onwards – given the counterfactual scenario, where the tax legislation of 2001 was upheld throughout the sample period calculated using register data (see Heebøll et al. (2013)). The related price graphs and individual area results are shown in Figure E.6 and Table E.6, Appendix E.4. As seen, the effects are relatively small, compared to the previous results, but they do seem to vary to a large degree across regions. Here the effects also vary depending on the model. The property tax freeze also had a larger effect in geographical centers and suburbs. However, this does not only depend on the market structure as such, but also on the fact that the tax cut resulting from the nominal tax freeze has the greatest effect in areas where prices increase the most (see Figure 4 in Section 2.3). Given these results, the nominal freeze is clearly price destabilizing. From the objective of achieving a more stable housing price development going forward, the results suggest that an abolishment of the nominal tax freeze.

Table 11: Price increases in the CF scenario without the tax freeze policy (2000-07)

	Unrestricted model				Restricted model			
	Geo. centers	Suburbs	Rural areas	National	Geo. centers	Suburbs	Rural areas	National
CVAR simulations								
Act. sim. price increase (%)	83	60	36	55	83	57	36	55
CF. sim. price increase (%)	73 (1.7)	52 (1.2)	35 (0.8)	50 (0.7)	74 (1.3)	51 (1.0)	35 (0.7)	50 (0.6)
Abs. deviation (pp.)	−10 (0.7)	−8 (0.7)	−1 (0.2)	−5 (0.4)	−9 (1.2)	−7 (0.9)	−2 (0.2)	−5 (0.4)
Relative deviation (%)	−12 (1.4)	−14 (1.2)	−4 (0.6)	−9 (0.7)	−11 (1.4)	−12 (1.5)	−4 (0.7)	−9 (0.7)
GVAR simulations								
Act. sim. price increase (%)	88	69	40	60	86	68	39	59
CF. sim. price increase (%)	79 (2.3)	64 (1.6)	37 (0.9)	56 (1.2)	79 (2.0)	64 (1.4)	37 (0.7)	55 (1.0)
Abs. deviation (pp.)	−8 (1.8)	−5 (1.2)	−2 (0.5)	−5 (1.0)	−7 (1.6)	−5 (0.9)	−2 (0.4)	−4 (0.7)
Relative deviation (%)	−9 (1.9)	−7 (1.5)	−6 (1.2)	−8 (1.5)	−8 (1.7)	−7 (1.2)	−5 (0.8)	−7 (1.1)

Note: Prices are simulated based on the CF scenario where the property tax rules of 2001 were keep throughout the sample period (affecting MFY and UC in the models) (simulated from 2000q1 to 2007q1) (see Appendix D for details). Numbers in parentheses are standard errors calculated based on bootstrap simulation with 200 replications. The *Abs. deviations* are defined as *CF. sim. price increase* minus *Act. sim. price increase*. *Relative deviations* are defined as *CF. sim. price increase* divided by *Act. sim. price increase* - 1.

9 Concluding remarks

In this paper, we have analyzed the price formation of 14 Danish housing markets, focusing on the diverse regional price boom preceding the recent financial crisis. Special emphasis is put on the three simultaneous policy impulses of the early 2000s, with the intent of determining their relative importance: *i*) the financial deregulation and introduction of ARM and IOM, *ii*) the expansionary fiscal and monetary policy, and *iii*) the property tax freeze from 2002 and onwards.

In order to analyze and control for important price ripple effects between the regional markets, we estimated and compared the results of a standard CVAR and a global VAR model approach. Furthermore, to ensure identification of the simultaneous policy impulses, we have imposed panel restrictions in line with the random coefficients modelling approach.

From 14 initially unrestricted CVAR models, we have been able to identify theoretically sound inverse housing demand relationships for all areas. Furthermore, allowing for price ripple effects using a GVAR model, we find that prices in all markets are highly dependent on related markets.

Analyzing the market structures cross-sectionally in the two types of models using the panel RCM approach, the effect of financial deregulation and the introduction of new mortgage types are found to be related to proxies for the share of credit-rationed agents, parallel to the results in Anundsen and Heebøll (2013b) and Wheaton and Nechayev (2008). Furthermore, we find that the regional price spillover effects are related to the population density as found in Vansteenkiste (2007) and to the regional share of commuters. The latter may indicate that when housing prices increase in the bigger cites, people tend to move out to areas where they can still commute and keep their jobs in the city. On the other hand, the semi-elasticity on unemployment rate is found to depend negatively on the average daily commute distance pr. worker. Hence, in regions where the labor market is more integrated with the labor market in other regions, housing prices are also less sensitive to the unemployment rate of the particular region itself. The income elasticity is found to be significantly lower in the outer suburbs of Copenhagen and areas with a medium sized city – i.e. counties that include a city with between 100.000 and 250.000 citizens.

We use the estimated models to simulate regional housing prices through the boom period of 2000 to 2007. From simulations we find that the predictive power of the models are significantly increased when allowing for price ripple effects – especially in rural areas. The model generally has a higher predictive power in rural areas, in which the prices are highly dependent on prices in the bigger cities. Hence, it seems that the reason why the model is ”only” able to explain about 85% of the national Danish housing boom of 2000s is to be found in the price formation of the urban areas. One explanation could be that the models do not adequately account for the effects of expectations. At this point we find that urban areas are more exposed to adaptive expectations and housing price bubbles, as seen from the bubble builder indices of Abraham and Hendershott (1996). Prices in urban areas are also more sensitive to the extensive financial deregulations seen through the sample period. In the end, the increased urbanization seen in Denmark from 2005 is also another possible explanation.

Further, to analyze the effect of the different policy interventions of the 2000s, we simulated the models given different counterfactual scenarios. On an aggregated national scale and considering the results across models, we find that financial deregulation, especially in combination with the expansionary monetary policy, was the primary driver of the Danish housing boom in 2000s. The fiscal policy and the property tax freeze meant slightly less.

All policy interventions are found to be greatly dependent on which type of region we consider. Financial deregulation and monetary policy had a larger influence in larger cities and suburbs where the share of credit rationed agents is higher. Fiscal policy matters relatively more in rural counties. From these results and comparing the results from the CVAR and GVAR models, we conclude that the boom started in the urban areas, primarily as a result of the direct effects of financial deregulation and expansionary monetary policy. However, through the ripple effects – when considering the GVAR models – the price effects were strongly transmitted to the rural areas. Hence, in rural areas we primarily see indirect effects of these policy interventions.

Compared to the other political interventions analyzed i this paper, the property tax freeze has the characteristic of being an ”automatic *de*stabilizer” of the housing prices going forward. Hence, all though the price effects are relatively modest, the results clearly suggest that one should remove the nominal tax freeze on property. Regarding monetary and fiscal policy, the larger effect of monetary policy – especially in urban areas and especially after the introduction of ARMs – suggests that during times of expansionary monetary policy set by the ECB, using fiscal policy to stabilize the output gab will not sufficiently stabilize the housing markets. Policy-makers may therefore need to lower the interest rate sensitivity or apply other macro-prudential instruments, in order to sufficiently stabilize the Danish housing market. At this point, one should look to the urban areas, as the boom typically starts here, however, with strong spillover price effect on the rest of the country.

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Appendix A: Time series data

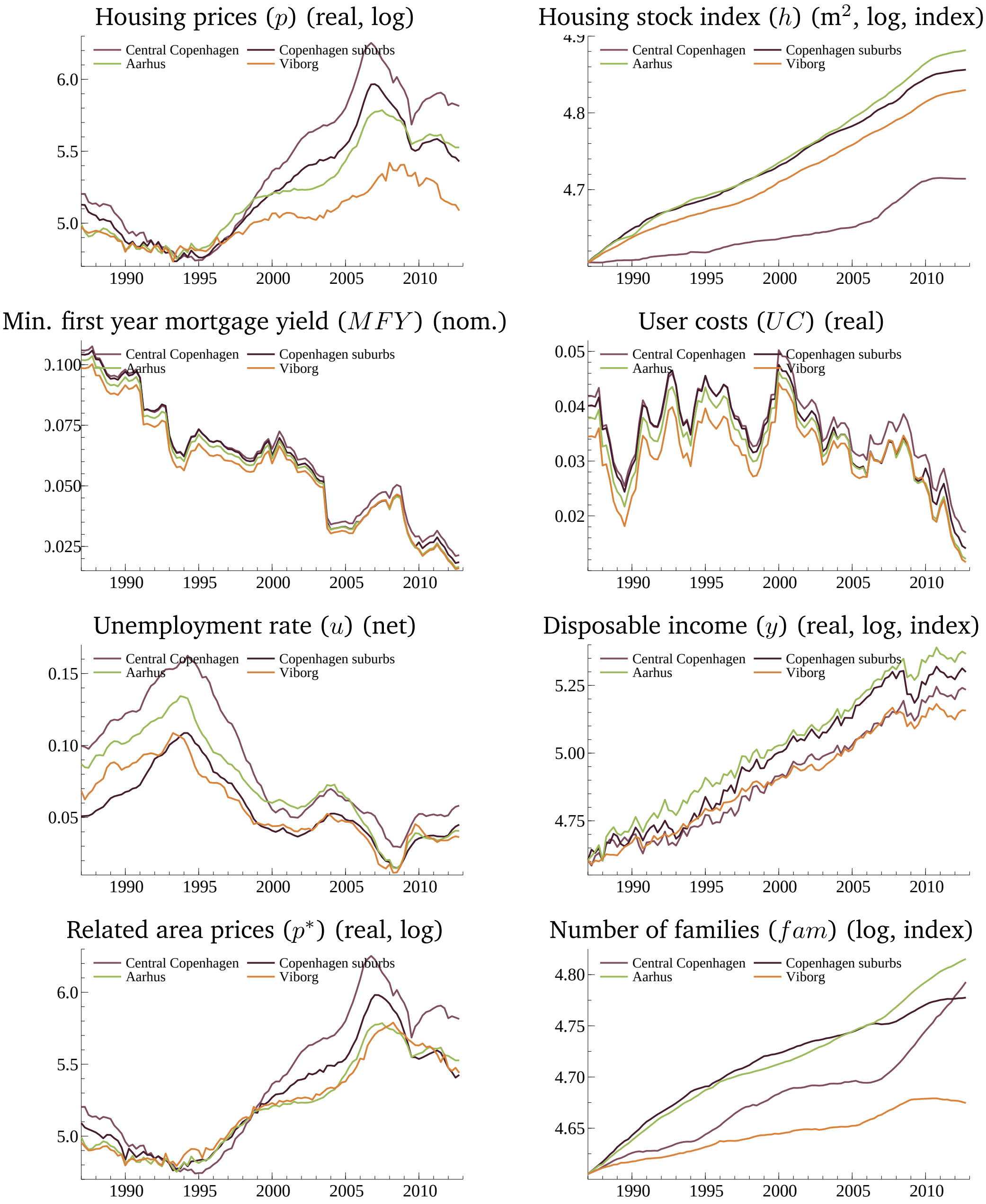
This Appendix describes the variable construction and data sources used in the model. Table A.1 shows the variables of the model including data sources while Figure A.1 shows graphs for all variables for 4 out of 14 areas. Generally all series are seasonally adjusted using a X12Arima model in PcGive.

Table A.1: Variables and data sources for each area

Endogenous variables	**Measurement**	**Data source**
Housing prices (p)	Real, log	RR, SKAT and DST*
Exogenous variables		
Housing stock (h)	Owner-occupied dwellings, log	DST register data, DST historical data
Min. first year mortgage yield (MFY)	Property taxes + the currently lowest possible interest and amortizations payments (nominal)***	DST register data and Dam et al. (2011)
Standard user cost (UC)	Property taxes + real fixed interest payments (30 years horizon)***	DST register data and the Mona databank**
Unemployment rate (u)	Net unemployment rate****	DST databank
Disposable income (y)	Real, log	DST register data, DA wage statistics*****, DST databank, Mona databank
Short run variables		
Population (fam)	Number of families, log	DSTs register data

Note: *) RR is the Association of Danish Mortgage Banks (Realkreditrådet), SKAT is the Danish tax authorities, DST is Statistics Denmark. **) Mona is the main macroeconomic model of the Danish Central Bank. ***) These are property taxes on newly purchased owner-occupied dwellings including both government property value tax (*ejendomsværdiskat*) and regional specific municipal land tax (*grundskyld*) (see Heebøll et al. (2013) for details) ****) The net unemployment rate excludes people jobs with government wage subsidies. *****) DA is the Danish employers' association.

Figure A.1: Data graphs for all TS-variables in the models



A.1 Housing prices (p)

For all counties (*amter*) except for Copenhagen center the housing price index is based on indices for single-family houses. In Copenhagen center we use a weighted average of price on condominiums and single-family houses. This is done partly because of data availability and party because condominiums represents a very high percentage of the housing stock in Copenhagen center (Copenhagen and Frederiksberg municipality), around 90%.

The regional housing price indices are constructed from three data sources: A) From 1987 to 1992 we use two types of historical data. *i*) From the Danish tax authorities (SKAT) we have quarterly data on housing prices in so called *municipality groups* (CG), divided as follows:

1. CG 1 is the center of Copenhagen center (København and Frederiksberg municipality),
2. CG 2 is the suburbs of Copenhagen (Copenhagen county),
3. CG 3 is the Frederiksborg and Roskilde municipality,
4. CG 4 is all other municipalities with a population of more than 50.000 people. That is Aarhus, Odense, Aalborg, Esbjerg, Kolding, Randers and Vejle municipality,
5. CG 5 is all municipalities with a population between 25.000 and 50.000 people
6. CG 6 is all municipalities with a population between 10.000 and 25.000 people
7. CG 7 is all municipalities with a population between 5.000 and 10.000 people
8. CG 8 the rest.

ii) From Statistics Denmark we have half-year data on housing prices on county level. In all counties but Copenhagen center and the suburbs of Copenhagen we interpolate the half year county level data from Statistics Denmark to quarterly data using the relevant quarterly data on municipality groups from SKAT. Here we have used the Chow Lin interpolation method.

After 1992 we have quarterly housing prices for single family dwellings on municipality level from the Association of Danish Mortgage Banks (*Realkreditrådet*). These series are converted from the municipality structure after the reform in 2006 to counties based on population shares in 2006.

A.2 Housing stock (h)

The regional figures for the housing stock are based on two data sources on county level. These are yearly figures on owner-occupied dwelling square meters from register data, Statistics Denmark (DST) and quarterly figures on number of newly constructed, completed square meters living area for year-round occupancy. Here we also use the Chow Lin interpolation method.

A.3 User cost (UC)

The standard real user cost on housing consist of real interest payments after interest deduction plus property taxes. The former is approximated by the interest payments of a 30-year fixed-rate mortgage bond, after standard interest deductions and inflation expectations, taken from the MONA database of the Danish Central Bank. The latter is based on register data from Statistics Denmark, calculated in Heebøll et al. (2013). In Denmark the property tax consist of a universal government property value tax (*ejendomsværdiskat*) based on the public property assessment and a regional specific municipal land tax (*grundskyld*). For the municipal land tax we use actual payments of permanent residences in the county, while the universal government property value tax – the former rent tax on owner-occupiers houses (*lejeværdi af egen bolig*, before 2000) – is based on the tax payments on newly purchased homes without any special tax deductions (see Heebøll et al. (2013) for details). We do not include capital gains in the user costs. In several previous analysis it is found that Danish housing price expectations are closely related to the lagged prices differences (see Dam et al. (2011) and references therein).

A.4 Minimum first-year yield (MFY)

The minimum first year yield mortgages are taken from Dam et al. (2011), defined as the lowest nominal first-year interest payments and amortizations on newly issued mortgages, plus the average regional property tax rate – as described above.

A.5 Unemployment rate (u)

Here we use quarterly net unemployment rates on county level from the Statbank of Statistic Denmark. Net unemployment rates includes people on job-subsidies from the government. After 2006 the series are converted from the municipality structure after the reform in 2006 to counties, based on population shares in 2006.

A.6 Disposable income (y)

Here we use the sum of disposable income yearly on county level from register data, Statistics Denmark (DST). This is further interpolated to quarterly data using county level wage statistics from confederation of Danish Employers (DA), county level unemployment rate data, as well as national disposable income, GVA in urban industries and agricultural sector from the MONA database of the Danish Central Bank.

A.7 Demographics (fam)

For the demographic variable we use the number for families taken from (and defined) in the register data, Statistics Denmark (DST). People are defines as a couple in the same family if they are either; *i*) *married couples*, *ii*) *in a registered partnership*, *iii*) *cohabiting child couples*, meaning that the two people have at least one common child in the Danish social security number, or *iv*) *cohabiting non-child couples*, meaning that they live together, are of opposite sex with under 15 years of age difference and are not in close kinship with each other.

Further people are defined as children living at home as part of a family if they; *i*) live at the same address as at least one parent, *ii*) their age is below 25, *iii*) they have never been married or in a registered partnership, *iv*) they are not involved in cohabiting couples.

The number for families are further interpolated to quarterly data using the total population size at county level, quarterly, from the Statbank of Statistic Denmark. The total population figures are converted from the municipality structure after the reform in 2006 to counties based on population shares in 2006.

Appendix B: CVAR specification and results

Table B.1 below shows the tests for lag-length and specification test of the unrestricted CVAR models including an impulse dummy in 1990:01. Table B.2 and B.3 shows the estimated long-run coefficient of the unrestricted and restricted models.

Table B.1: Specification test for the unrestricted CVAR

Test	ACI	ACI	ACI	ACI	AR*	ARCH *	Norm.*	Lags used
Lags / dist	1	2	3	4	F^{**}	F^{***}	$\chi^2(2)$	
Cph, Central	**-3.92**	-3.91	-3.83	-3.82	0.01	0.02	0.01	1
Cph Suburbs	-4.64	**-4.72**	-4.71	-4.69	0.06	0.59	0.50	2
Frederiksborg	**-5.10**	-5.03	-4.93	-4.88	0.74	0.68	0.72	1
Roskilde	-4.56	**-4.57**	-4.56	-4.56	0.76	0.01	0.03	2
Aarhus	-4.74	**-4.84**	-4.84	-4.80	0.04	0.05	0.17	2
Fyn	-4.98	-4.93	-4.95	**-5.15**	0.42	0.29	0.11	1
Vejle	-4.53	**-4.54**	-4.42	-4.32	0.11	0.00	0.56	2
W. Zealand	-4.23	-4.23	-4.22	**-4.28**	0.55	0.31	0.54	1
N. Jutland	**-4.88**	-4.83	-4.82	-4.81	0.24	0.94	0.23	1
S. Jutland	-4.09	-4.08	-4.34	**-4.47**	0.01	0.96	0.02	1
Ribe	-4.21	**-4.24**	-4.14	-4.05	0.93	0.46	0.41	2
Storstrom	-4.10	-4.18	-4.08	**-4.28**	0.07	0.05	0.77	2
Viborg	-4.44	**-4.51**	-4.46	-4.48	0.10	0.05	0.05	2
Ringkobing	-4.66	**-4.81**	-4.71	-4.75	0.78	0.50	0.84	2

Note: The lags refer to the lags in the models on ECM form. *) For the AR, ARCH and normality the table shows p-values. **) The ARCH F-tests either have (1,99) or (1,100) degrees of freedom depending on the number of lags. ***) The normality F-tests either have (2,65) or (2,74) degrees of freedom depending on the number of lags.

Table B.2: Results of the unrestricted ECMs (long-run coefficients)

	β_p	β_h	β_{MFY}	β_{UC}	β_u	β_y	β_t	α
Cph, Central	1.00	3.63 (0.51)	18.68 (2.05)	2.30 (0.25)	6.87 (2.34)	−4.36 (−1.76)	0.03 (1.60)	−0.10 (−5.00)
Cph Suburbs	1.00	21.72 (1.42)	20.13 (2.20)	−7.18 (−1.07)	8.37 (1.97)	−2.67 (−2.14)	0.00 (0.02)	−0.25 (−3.92)
Frederiksborg	1.00	11.20 (1.61)	18.72 (3.57)	4.33 (0.89)	−1.40 (−0.35)	−6.19 (−5.06)	0.02 (1.31)	−0.23 (−5.99)
Roskilde	1.00	10.09 (0.96)	30.47 (2.63)	4.66 (0.44)	9.07 (1.33)	−6.57 (−2.35)	0.04 (1.34)	−0.18 (−4.30)
Aarhus	1.00	8.98 (0.86)	26.35 (2.07)	10.99 (1.15)	4.61 (0.75)	−2.60 (−0.89)	0.01 (0.31)	−0.15 (−3.28)
Fyn	1.00	13.71 (3.35)	0.48 (0.17)	1.04 (0.49)	2.08 (1.31)	−4.11 (−5.44)	−0.01 (−1.15)	−0.28 (−5.85)
Vejle	1.00	3.12 (1.19)	4.87 (0.99)	3.83 (1.01)	0.93 (0.34)	−1.59 (−1.40)	0.00 (−0.12)	−0.32 (−3.76)
W. Zealand	1.00	13.55 (6.53)	−6.63 (−1.82)	8.13 (3.09)	−3.00 (−1.66)	−6.78 (−5.90)	0.00 (−0.21)	−0.42 (−5.60)
N. Jutland	1.00	5.62 (1.33)	6.13 (1.20)	6.09 (1.49)	0.74 (0.35)	−5.75 (−3.97)	0.02 (1.50)	−0.29 (−4.37)
S. Jutland	1.00	3.65 (0.99)	−0.97 (−0.39)	3.01 (1.61)	2.08 (1.38)	−2.51 (−3.94)	0.00 (0.13)	−0.63 (−5.84)
Ribe	1.00	−3.29 (−0.69)	7.88 (2.01)	1.21 (0.54)	4.59 (1.57)	−2.67 (−2.02)	0.03 (1.76)	−0.24 (−3.41)
Storstrom	1.00	3.32 (1.04)	7.13 (1.48)	3.31 (0.82)	2.31 (0.87)	−2.80 (−2.28)	0.01 (0.77)	−0.40 (−4.36)
Viborg	1.00	−8.15 (−3.76)	9.14 (3.91)	−3.93 (−2.23)	7.13 (4.31)	−2.26 (−3.51)	0.04 (5.03)	−0.47 (−5.18)
Ringkobing	1.00	−0.88 (−0.26)	13.87 (4.08)	1.51 (0.76)	4.01 (1.24)	−3.06 (−3.16)	0.03 (2.41)	−0.55 (−5.86)
Aggregated area coefficients								
Geo. centers	1.00	11.53	21.83	2.15	6.59	-3.18	0.01	-0.17
Suburbs	1.00	7.95	16.50	4.23	2.03	-4.59	0.02	-0.25
Rural areas	1.00	4.85	4.23	2.91	2.15	-4.04	0.01	-0.39

Note: Values in parentheses are t-values.

Table B.3: Results of the restricted ECMs (long-run coefficients)

	β_p	β_h	β_{MFY}	β_{UC}	β_u	β_y	β_t	α	p-val
Cph, Central	1.00	−0.18 (−0.03)	12.06 (9.15)	0.22 (0.04)	5.94 (5.22)	−2.64 (−3.03)	0.02 (2.52)	−0.09 (−5.00)	0.09
Cph Suburbs	1.00	32.52 (2.55)	18.53 (13.69)	2.67 (0.73)	5.79 (5.15)	−2.64 (−3.03)	−0.01 (−0.95)	−0.08 (−3.96)	0.65
Frederiksborg	1.00	5.63 (1.13)	14.66 (11.41)	4.04 (1.13)	3.04 (2.37)	−5.23 (−9.80)	0.03 (2.40)	−0.12 (−5.53)	0.89
Roskilde	1.00	9.53 (1.39)	14.84 (11.61)	4.46 (2.08)	2.55 (1.88)	−5.23 (−9.80)	0.02 (0.90)	−0.08 (−3.62)	0.62
Aarhus	1.00	3.87 (0.55)	16.10 (11.98)	1.89 (0.55)	2.83 (3.95)	−2.64 (−3.03)	0.02 (0.80)	−0.07 (−3.51)	0.86
Fyn	1.00	22.27 (5.07)	8.33 (6.84)	1.62 (1.28)	2.86 (4.02)	−5.23 (−9.80)	−0.01 (−1.58)	−0.14 (−7.12)	0.74
Vejle	1.00	2.31 (1.11)	9.26 (7.61)	1.93 (2.07)	3.22 (4.81)	−2.71 (−7.54)	0.01 (2.37)	−0.20 (−4.96)	0.50
W. Zealand	1.00	10.17 (7.27)	2.06 (1.59)	2.46 (0.91)	0.74 (0.66)	−5.23 (−9.80)	0.01 (1.61)	−0.23 (−6.97)	0.78
N. Jutland	1.00	2.92 (1.07)	8.62 (7.09)	1.52 (1.75)	1.96 (2.14)	−5.23 (−9.80)	0.03 (4.77)	−0.13 (−5.72)	0.39
S. Jutland	1.00	2.20 (0.71)	−0.54 (−0.41)	1.75 (1.29)	3.35 (4.94)	−2.71 (−7.54)	0.01 (1.05)	−0.34 (−5.43)	0.53
Ribe	1.00	−2.56 (−0.63)	9.99 (8.15)	1.74 (0.98)	3.85 (5.35)	−2.71 (−7.54)	0.02 (2.61)	−0.24 (−4.66)	0.45
Storstrom	1.00	4.51 (1.84)	4.99 (3.72)	2.38 (0.35)	0.36 (0.32)	−2.71 (−7.54)	0.00 (0.35)	−0.20 (−6.07)	0.45
Viborg	1.00	−0.54 (−0.29)	7.53 (6.19)	1.44 (1.33)	3.74 (4.49)	−2.71 (−7.54)	0.02 (4.92)	−0.25 (−5.12)	0.93
Ringkobing	1.00	−1.96 (−1.11)	11.74 (9.41)	1.62 (0.73)	4.25 (5.12)	−2.71 (−7.54)	0.03 (5.91)	−0.34 (−6.56)	0.13
Aggregated area coefficients									
Geo. centers	1.00	12.15	15.62	1.62	4.81	-2.64	0.01	-0.08	0.54
Suburbs	1.00	5.36	12.72	3.37	2.98	-4.30	0.02	-0.14	0.68
Rural areas	1.00	6.17	6.85	1.78	2.55	-3.97	0.01	-0.22	0.55

Note: Values in parentheses are t-values.

Appendix C: GVAR specification and results

Table C.1 below shows the tests for lag-length and specification test of the unrestricted CVAR models including an impulse dummy in 1990:01. Table C.2 and C.4 shows the estimated long-run coefficient of the unrestricted and restricted models, while Table C.3 and C.5 shows the total impact elasticities.

Table C.1: Specification test for the unrestricted CVAR

Test	ACI	ACI	ACI	ACI	AR*	ARCH *	Norm.*	Lags used
Lags / dist	1	2	3	4	F^{**}	F^{***}	$\chi^2(2)$	
Cph, Central	**-4.51**	-4.43	-4.40	-4.47	0.70	0.04	0.03	1
Cph Suburbs	-5.18	-5.24	-5.19	**-5.42**	0.23	0.66	0.45	2
Frederiksborg	-5.33	**-5.34**	-5.24	-5.34	0.63	0.76	0.63	2
Roskilde	-4.95	-5.10	-5.14	**-5.22**	0.12	0.67	0.77	2
Aarhus	-5.10	-5.23	**-5.26**	-5.24	0.00	0.76	0.03	2
Fyn	-5.11	-5.06	-5.06	**-5.28**	0.87	0.44	0.09	1
Vejle	-4.66	-4.68	**-4.72**	-4.61	0.44	0.09	0.44	2
W. Zealand	-4.33	-4.44	-4.41	**-4.52**	0.00	0.42	0.09	2
N. Jutland	-5.05	-5.06	-5.00	**-5.10**	0.01	0.85	0.43	2
S. Jutland	-4.15	-4.11	-4.34	**-4.44**	0.04	0.82	0.02	1
Ribe	**-4.28**	-4.27	-4.14	-4.06	0.77	0.40	0.42	1
Storstrom	-4.19	-4.27	-4.24	**-4.48**	0.04	0.10	0.99	2
Viborg	-4.54	-4.53	-4.49	**-4.60**	0.14	0.01	0.05	1
Ringkobing	-4.86	-4.97	-5.02	**-5.03**	0.51	0.50	0.28	2

Note: The lags refer to the lags in the models on ECM form. *) For the AR, ARCH and normality the table shows p-values. **) The ARCH F-tests either have (1,99) or (1,100) degrees of freedom depending on the number of lags. ***) The normality F-tests either have (2,65) or (2,74) degrees of freedom depending on the number of lags.

Table C.2: Results of the unrestricted GECM (long-run coefficients)

	β_p	β_h	β_{MFY}	β_{UC}	β_u	β_y	β_{p*}	β_t	α
Cph, Central	1.00	−0.65 (−0.13)	6.87 (1.01)	1.29 (0.20)	5.76 (2.47)	−1.63 (−0.82)	−0.54 (−1.82)	0.01 (0.92)	−0.10 (−4.04)
Cph Suburbs	1.00	−2.53 (−0.63)	1.75 (0.74)	−4.19 (−2.48)	−0.41 (−0.36)	−0.38 (−0.82)	−0.86 (−10.06)	0.01 (1.11)	−0.27 (−3.70)
Frederiksborg	1.00	2.65 (0.95)	1.75 (0.74)	−1.23 (−0.65)	−3.28 (−2.04)	−2.43 (−4.54)	−0.75 (−8.86)	0.01 (1.30)	−0.22 (−6.00)
Roskilde	1.00	−0.97 (−0.34)	0.91 (0.30)	−1.60 (−0.62)	0.20 (0.11)	0.36 (0.45)	−1.01 (−7.55)	0.00 (0.50)	−0.18 (−4.34)
Aarhus	1.00	−4.30 (−1.22)	10.43 (2.50)	0.43 (0.14)	4.37 (2.07)	−0.19 (−0.19)	−0.51 (−4.39)	0.02 (1.65)	−0.15 (−3.29)
Fyn	1.00	2.88 (0.95)	1.20 (0.54)	−0.16 (−0.11)	1.81 (1.70)	−2.88 (−5.52)	−0.39 (−3.85)	0.01 (1.55)	−0.29 (−5.86)
Vejle	1.00	0.90 (0.53)	1.34 (0.48)	−0.26 (−0.12)	−0.62 (−0.39)	−1.38 (−2.20)	−0.58 (−3.62)	0.00 (0.63)	−0.32 (−3.77)
W. Zealand	1.00	4.79 (3.46)	−3.05 (−1.49)	−0.11 (−0.05)	−2.84 (−2.64)	−2.18 (−2.69)	−0.86 (−5.19)	0.00 (−0.39)	−0.40 (−5.48)
N. Jutland	1.00	−3.60 (−1.91)	3.90 (2.00)	−0.08 (−0.05)	2.67 (3.16)	−1.04 (−1.69)	−0.53 (−5.56)	0.02 (3.10)	−0.29 (−4.35)
S. Jutland	1.00	−0.45 (−0.23)	3.85 (2.43)	−1.41 (−1.08)	2.38 (3.01)	−0.12 (−0.24)	−0.58 (−5.10)	0.00 (1.03)	−0.65 (−5.81)
Ribe	1.00	4.30 (0.70)	3.24 (0.73)	1.53 (0.65)	−0.06 (−0.02)	−2.67 (−1.94)	−0.54 (−1.89)	0.01 (0.35)	−0.26 (−3.38)
Storstrom	1.00	−0.12 (−0.07)	2.39 (0.99)	−2.19 (−1.07)	−0.76 (−0.53)	−0.80 (−1.29)	−0.96 (−5.82)	0.01 (1.30)	−0.40 (−4.15)
Viborg	1.00	−2.69 (−1.06)	5.05 (2.72)	−3.15 (−2.46)	2.22 (1.24)	−1.45 (−2.95)	−0.56 (−3.02)	0.02 (2.62)	−0.52 (−5.33)
Ringkobing	1.00	2.60 (1.45)	2.30 (1.59)	1.39 (2.07)	−0.66 (−0.45)	−1.11 (−3.16)	−0.78 (−7.57)	0.00 (0.28)	−0.65 (−6.22)
Aggregated area coefficients									
Geo. centers	1.00	-2.54	6.39	-0.84	3.21	-0.71	-0.63	0.01	-0.17
Suburbs	1.00	1.12	1.39	-0.97	-1.45	-1.36	-0.75	0.01	-0.25
Rural areas	1.00	0.76	2.28	-0.43	0.83	-1.59	-0.63	0.01	-0.41

Note: Values in parentheses are t-values.

Table C.3: Total impact elasticities of the unrestricted GECM ($\widetilde{\beta}$)

	$\widetilde{\beta}_{MFY}$	$\widetilde{\beta}_{UC}$	$\widetilde{\beta}_u$	$\widetilde{\beta}_y$
Cph, Central	15.18	-1.25	10.00	-3.11
Cph Suburbs	15.06	-5.30	7.90	-2.91
Frederiksborg	13.04	-3.95	3.27	-4.66
Roskilde	15.42	-5.24	7.23	-3.23
Aarhus	17.89	-1.60	7.93	-1.96
Fyn	7.53	-1.34	4.74	-4.00
Vejle	9.10	-1.57	3.20	-3.19
W. Zealand	8.16	-2.52	2.55	-5.04
N. Jutland	10.71	-1.28	5.72	-2.77
S. Jutland	10.25	-2.57	5.29	-2.05
Ribe	9.18	0.38	2.72	-4.26
Storstrom	13.99	-4.82	4.62	-4.20
Viborg	11.39	-4.15	5.03	-3.28
Ringkobing	10.93	-0.34	3.05	-3.73
Aggregated area coefficients				
Geo. centers	16.08	-2.73	8.58	-2.65
Suburbs	12.17	-3.39	4.21	-3.77
Rural areas	10.05	-1.95	4.38	-3.63

Note: These area calculated using (17).

Table C.4: Results of the restricted GECM (long-run coefficients)

	β_p	β_h	β_{MFY}	β_{UC}	β_u	β_y	β_{p*}	β_t	α	p-val
Cph, Central	1.00	−0.65 (−0.13)	6.87 (2.26)	1.29 (1.40)	5.76 (7.48)	−1.63 (−3.89)	−0.54 (−4.78)	0.01 (0.92)	−0.10 (−4.04)	1.00
Cph Suburbs	1.00	−0.86 (−0.26)	2.70 (0.73)	−2.13 (−2.85)	0.07 (0.09)	−0.59 (−1.42)	−0.77 (−6.40)	0.01 (1.60)	−0.23 (−3.41)	0.98
Frederiksborg	1.00	0.25 (0.05)	2.26 (0.70)	−1.28 (−1.13)	−2.48 (−2.67)	−2.12 (−6.51)	−1.03 (−12.00)	0.02 (1.63)	−0.10 (−5.17)	0.27
Roskilde	1.00	2.93 (0.63)	2.77 (1.29)	0.37 (0.25)	−2.84 (−2.99)	−2.12 (−6.51)	−1.09 (−12.44)	0.01 (1.13)	−0.08 (−3.53)	0.14
Aarhus	1.00	−2.82 (−0.92)	4.15 (3.80)	2.03 (2.86)	1.47 (3.36)	−0.59 (−1.42)	−0.44 (−8.75)	0.01 (1.38)	−0.13 (−2.72)	0.31
Fyn	1.00	0.29 (0.16)	2.33 (2.88)	−0.93 (−1.75)	1.43 (3.28)	−2.12 (−6.51)	−0.54 (−10.79)	0.01 (3.49)	−0.32 (−5.42)	0.21
Vejle	1.00	0.63 (0.60)	2.75 (4.70)	0.19 (0.46)	0.81 (1.77)	−1.18 (−4.88)	−0.58 (−11.87)	0.01 (1.96)	−0.34 (−3.56)	0.00
W. Zealand	1.00	4.30 (5.16)	1.21 (1.13)	−1.58 (−2.52)	−1.52 (−2.33)	−2.12 (−6.51)	−0.88 (−17.21)	0.00 (1.87)	−0.36 (−5.01)	0.33
N. Jutland	1.00	−4.14 (−2.56)	2.53 (4.15)	−0.52 (−1.08)	2.14 (3.88)	−2.12 (−6.51)	−0.56 (−12.29)	0.02 (7.18)	−0.20 (−4.05)	0.04
S. Jutland	1.00	2.89 (1.27)	1.35 (1.25)	−0.95 (−1.86)	1.13 (2.60)	−1.18 (−4.88)	−0.55 (−11.97)	0.00 (0.30)	−0.45 (−5.35)	0.49
Ribe	1.00	3.78 (0.96)	3.10 (3.67)	0.80 (1.83)	0.51 (0.99)	−1.18 (−4.88)	−0.55 (−12.03)	0.00 (−0.17)	−0.24 (−3.27)	0.07
Storstrom	1.00	0.05 (0.02)	0.53 (0.15)	−4.36 (−3.37)	−1.18 (−1.87)	−1.18 (−4.88)	−0.82 (−18.20)	0.00 (1.38)	−0.25 (−3.69)	0.07
Viborg	1.00	0.78 (0.82)	2.33 (3.65)	−0.82 (−1.49)	−0.43 (−0.67)	−1.18 (−4.88)	−0.62 (−13.65)	0.01 (3.09)	−0.51 (−4.72)	0.90
Ringkobing	1.00	1.58 (2.08)	3.41 (3.77)	1.05 (2.28)	0.00 (−0.01)	−1.18 (−4.88)	−0.70 (−16.13)	0.00 (2.59)	−0.62 (−6.28)	0.03
Aggregated area coefficients										
Geo. centers	1.00	-1.48	4.54	0.40	2.37	-0.92	-0.58	0.01	-0.15	0.76
Suburbs	1.00	1.05	2.57	-0.34	-1.36	-1.77	-0.88	0.01	-0.19	0.14
Rural areas	1.00	0.62	2.14	-0.90	0.51	-1.65	-0.64	0.01	-0.35	0.24

Note: Values in parentheses are t-values.

Table C.5: Total impact elasticities of the unrestricted GECM ($\widetilde{\beta}$)

	$\widetilde{\beta}_{MFY}$	$\widetilde{\beta}_{UC}$	$\widetilde{\beta}_u$	$\widetilde{\beta}_y$
Cph, Central	13.60	0.78	9.13	-3.20
Cph Suburbs	12.83	-1.44	6.59	-2.99
Frederiksborg	15.76	-1.81	5.36	-5.27
Roskilde	18.08	-0.60	4.73	-6.28
Aarhus	10.96	1.69	4.26	-2.65
Fyn	9.69	-0.77	4.38	-4.19
Vejle	9.66	0.25	3.67	-3.37
W. Zealand	12.52	-1.81	3.01	-5.78
N. Jutland	9.18	-0.50	4.70	-4.30
S. Jutland	7.47	-1.07	3.57	-3.39
Ribe	8.72	0.58	2.85	-3.30
Storstrom	10.78	-4.85	2.74	-4.80
Viborg	8.62	-1.04	2.10	-3.57
Ringkobing	10.19	0.72	2.43	-3.80
Aggregated area coefficients				
Geo. centers	12.43	0.35	6.59	-2.94
Suburbs	14.08	-0.76	4.58	-4.82
Rural areas	9.68	-1.03	3.47	-4.20

Note: These area calculated using (17).

Appendix D: Calculations related to counterfactual scenarios

In this appendix we outline the assumptions and constructions of the different counterfactual experiments applied to the estimated models.

D.1 The counterfactual scenario without the financial deregulation

In the actual scenario The MFY is given by a 30 year nominal interest rate on a standard mortgage plus amortizations from 1987 to 1999. Hereafter, the lowest interest rate shift down to the interest rate on one-year ARM. Further in 2003 the the amortizations drops to zero as housing buyers are allowed to option to defer amortizations. In the counterfactual scenario analyzing the effects of ARMs we will consider the scenario where the MFY included a 30-year mortgage rate throughout the sample period, while everything else is as in the actual scenario. In the counterfactual scenario analyzing the effects of IOMs we will consider the scenario where the MFY included a the amortizations of a 30-year annuity throughout the sample period, while everything else is as in the actual scenario. The two scenarios are shown in Figure 2 in Section 2.1.

D.2 The counterfactual scenario with a ”neutral” economic policy

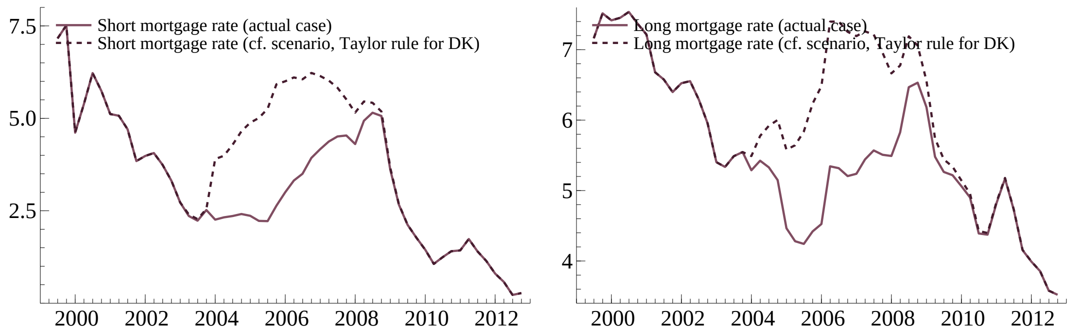
Table D.1 below show the ECM model results where we estimate how changes in the monetary policy rate affects the long and short mortgages rates. Here the mortgage rates are the only endogenous variables. It is assumed that the policy rate is exogenously given by the ECB. Both models have a lag length of $l = 1$. From these models, the long and short mortgage rate are simulated under the scenario that the monetary policy rate follows the ECB Taylor-rule applied Danish economic conditions from 2004 to 2007 (the full-information case of revised output-gap and inflation figures, see Figure 3 and Heebøll (2014)). The short and long mortgage rates are shown in actual and the simulated counterfactual scenario in Figure D.1.

Table D.1: ECM model for the mortgage rates termstructure

	i_{mr}	i_{pr}	c	$\alpha_{i_{mr}}$
Long rate (1999 - 2012)	1.00	-0.83	-0.03	-0.15
		(-3.2)	(-3.8)	(-2.9)
Short rate (2000 - 2012)	1.00	-1.10	0.00	-0.36
		(-15.6)	(-1.1)	(-4.1)

Note: In each model, the mortgage rate is the only endogenous variable. The i_{mr}s are nominal mortgage rates. The long rate is a 30 year mortgage rate, while the short rate is a 1 year mortgage rate. i_{pr} is the nominal policy rate, while c is a constant. The model is estimated on the sample from 2000q1 to 2012q4.

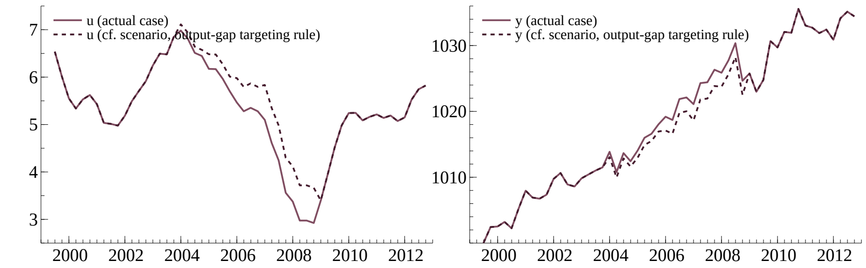
Figure D.1: Simulated mortage rates in the scenario where the policy rate follows the ECB Taylor-rule for Denmark (2004-07)



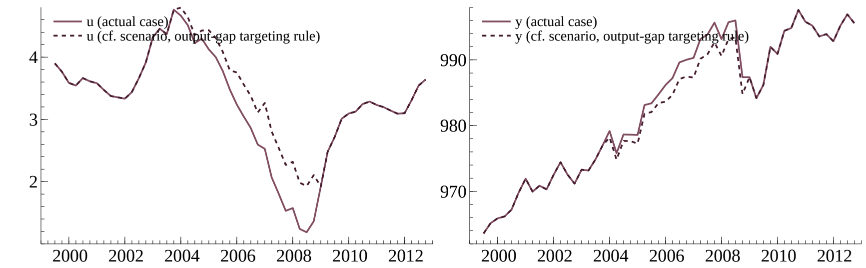
To find the effects of expansionary fiscal policy we estimate similar ECM models for unemployment rates and log disposable income (as the only endogenous variables), having GDP as the only exogenous variable. Here we analyze the situation where the fiscal policy followed the output-gap targeting rule in Linaa et al. (2008). These scenarios are calculated in Kraka (2012). The model estimation results are not reported but the actual and simulated counterfactual evolutions of unemployment rates and disposable income is shown in Figure D.2.

Figure D.2: Simulated regional unemployment rates and log disposable income in the scenario where the fiscal policy rate follows a output-gap targeting rule (2004-07)

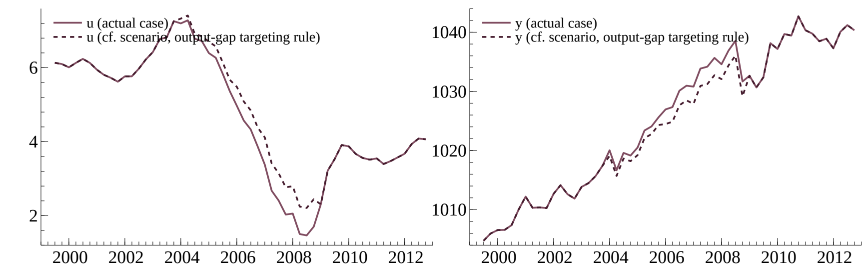
Copenhagen center



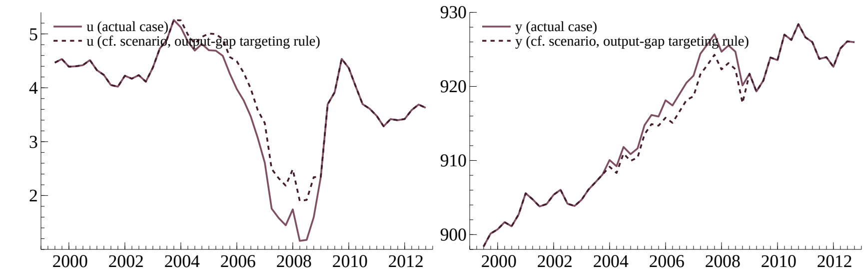
Freberiksborg



Aarhus



Viborg



Note: This is simulated based on regional ECM models including yi and national GDP, as well as ui and national GDP. The models are simulated in the case where fiscal policy follows the output-gap stabilizing rule of Linaa et al. (2008) with the GDP effects found in Kraka (2012).

D.3 The counterfactual scenario without the property tax freeze

In Heebøll et al. (2013) they calculate the effects of the property tax freeze in 2002 using register data. Specifically they calculate the counterfactual property taxes given that the tax law before 2002 was continued throughout the sample period. These will be used in the counterfactual simulations (see Heebøll et al. (2013) for graphs and details).

Appendix E: Model simulation results

E.1 Explanatory power of the models

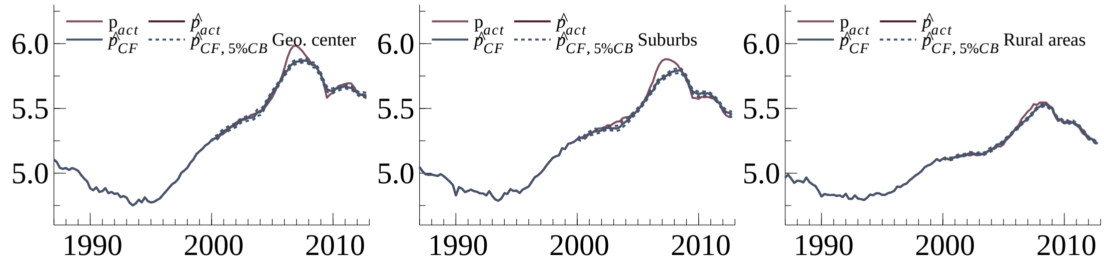
Table E.1: Price increases in the actual scenario (2000-07, predictive power)

	Geo. centers				Suburbs				Rural areas									
	Cph.c.	Cph.sub	Aarhus	Total	Fr.borg	Rosk.	Vejle	Total	Fyn	W. Zea.	N. Jut.	S. Jut.	Ribe	Storst.	Viborg	Ringk.	Total	National
Act. price increase (%)	138	114	76	107	104	89	61	83	49	75	36	31	30	73	24	39	44	71
Unrestricted CVAR																		
Sim. price increase (%)	111	73	56	77	81	55	48	61	38	68	32	27	24	69	21	29	38	55
	(3.6)	(2.7)	(2.3)	(1.6)	(2.7)	(2.2)	(1.8)	(1.3)	(1.5)	(2.1)	(2.4)	(1.5)	(1.0)	(2.3)	(1.3)	(1.3)	(0.7)	(0.6)
Abs. deviation (pp.)	-27	-41	-20	-30	-23	-34	-14	-22	-11	-6	-3	-4	-5	-4	-3	-10	-6	-16
Explanatory power (%)	80	64	73	72	77	62	78	74	78	91	90	87	82	95	89	75	86	78
Restricted CVAR																		
Sim. price increase (%)	111	93	53	83	74	52	44	57	39	66	31	27	22	61	21	26	36	55
	(2.6)	(2.3)	(2.2)	(1.4)	(2.6)	(2.1)	(1.9)	(1.4)	(2.1)	(2.0)	(1.9)	(1.2)	(0.6)	(1.5)	(1.3)	(2.0)	(0.6)	(0.6)
Abs. deviation (pp.)	-27	-21	-23	-24	-30	-37	-17	-26	-10	-9	-5	-5	-8	-11	-3	-13	-8	-16
Explanatory power (%)	80	82	70	78	72	59	73	69	80	89	86	86	73	84	86	68	82	78
Unrestriced GVAR																		
Sim. price increase (%)	109	93	65	88	83	74	52	69	42	71	33	29	26	66	21	34	40	60
	(3.1)	(2.2)	(1.5)	(1.5)	(2.2)	(2.6)	(1.3)	(1.3)	(1.2)	(1.6)	(1.7)	(1.3)	(1.2)	(1.7)	(1.1)	(1.4)	(0.7)	(0.8)
Abs. deviation (pp.)	-29	-21	-11	-19	-21	-15	-9	-14	-7	-4	-3	-2	-3	-7	-3	-5	-4	-10
Explanatory power (%)	79	82	85	82	80	84	85	83	85	95	93	93	89	91	89	88	90	85
Restricted GVAR																		
Sim. price increase (%)	108	92	63	86	83	74	51	68	41	70	33	30	27	63	21	33	39	59
	(3.1)	(1.9)	(1.0)	(1.5)	(2.4)	(3.1)	(1.0)	(1.6)	(1.2)	(1.8)	(1.5)	(1.3)	(1.1)	(1.9)	(0.9)	(1.0)	(0.7)	(0.9)
Abs. deviation (pp.)	-30	-22	-13	-21	-21	-15	-10	-15	-8	-5	-3	-1	-3	-10	-3	-6	-5	-11
Explanatory power (%)	78	81	83	80	80	83	84	82	84	94	93	96	91	87	89	86	90	84

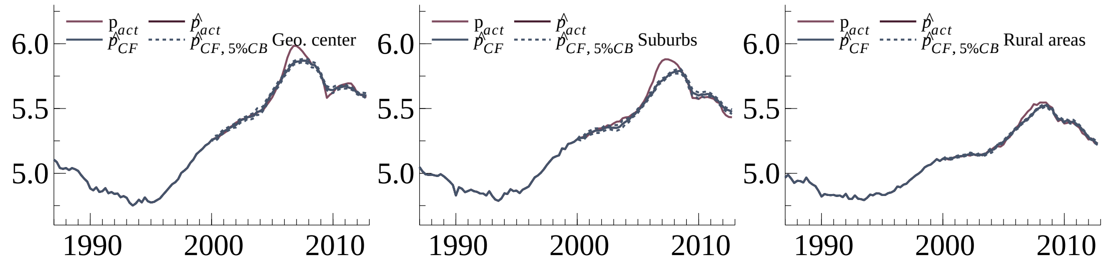
Note: pp. are percentage points. Values in parentheses are standard errors calculated using bootstrap simulations of 200 replications. *Abs. deviations* are defined as *Sim. price increase* minus *Act. price increase*. *Explanatory power* is defined as (*Act. price increase - Abs. deviations*)/*Act. price increase*.

Figure E.1: Simulated prices in the actual scenario (2000-07, explanatory power)

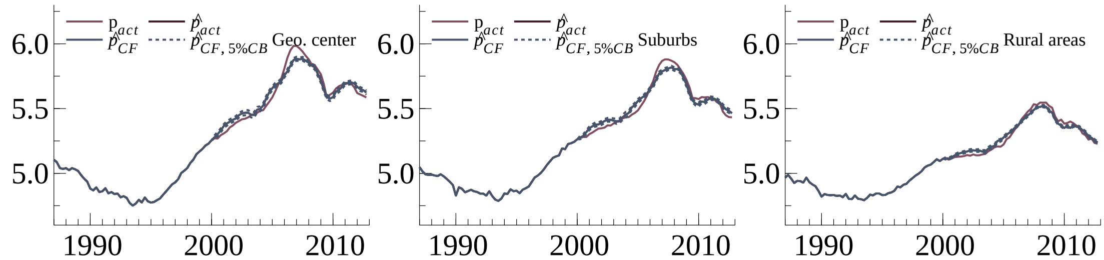
Unrestricted CVAR model



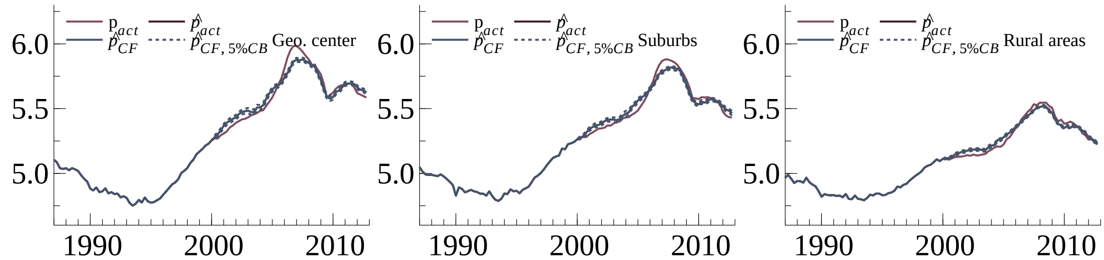
Restricted CVAR model



Unrestricted GVAR model



Restricted GVAR model



Note: Prices are simulated based on actual data for all exogenous variables (simulated from 2000q1 to 2007q1). The dotted lines are confidence bounds calculated using bootstrap simulations, 200 replications.

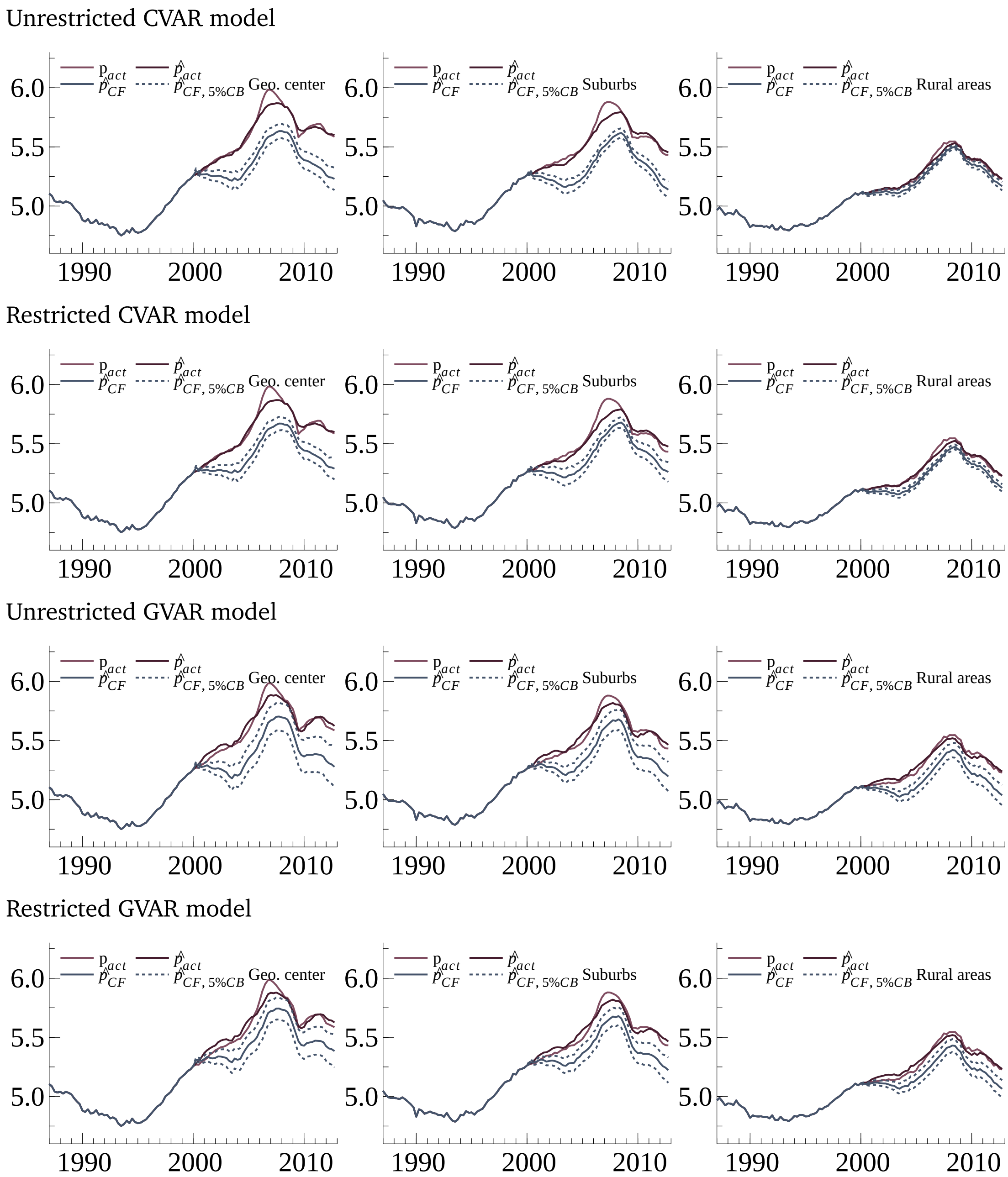
Table E.2: Price increases in the CF scenario without ARMs (2000-07)

	Geo. centers				Suburbs				Rural areas									
	Cph.c.	Cph.sub	Aarhus	Total	Fr.borg	Rosk.	Vejle	Total	Fyn	W. Zea.	N. Jut.	S. Jut.	Ribe	Storst.	Viborg	Ringk.	Total	National
Unrestricted CVAR																		
Act.sim.price increase (%)	111	90	56	83	81	55	44	60	38	68	32	27	21	60	20	27	36	55
CF.sim.price increase (%)	61	56	12	40	40	4	33	28	35	83	23	29	14	53	13	7	31	34
	(8.4)	(7.4)	(8.8)	(4.9)	(4.0)	(4.9)	(6.8)	(2.9)	(3.5)	(5.6)	(3.9)	(2.4)	(3.1)	(6.4)	(2.1)	(3.0)	(1.4)	(1.8)
Abs.deviation (pp.)	−50	−34	−44	−43	−41	−50	−11	−32	−3	15	−10	2	−7	−7	−7	−20	−6	−22
	(7.8)	(6.8)	(8.9)	(4.7)	(3.9)	(6.4)	(5.8)	(3.0)	(2.8)	(5.0)	(3.0)	(2.0)	(3.0)	(5.8)	(1.7)	(3.0)	(1.2)	(1.8)
Relative deviation (%)	−45	−38	−78	−52	−51	−92	−25	−54	−7	22	−30	8	−34	−12	−35	−74	−15	−40
	(6.7)	(7.8)	(16.2)	(5.7)	(5.0)	(11.8)	(13.3)	(5.1)	(7.6)	(7.3)	(9.9)	(7.2)	(11.9)	(9.7)	(8.1)	(11.2)	(3.3)	(3.2)
Restricted CVAR																		
Act.sim.price increase (%)	111	93	53	83	74	52	44	57	39	66	31	27	22	61	21	26	36	55
CF.sim.price increase (%)	61	53	28	46	46	28	30	36	26	64	20	31	10	51	13	13	27	35
	(7.3)	(6.6)	(5.1)	(4.2)	(4.3)	(5.4)	(5.7)	(2.9)	(5.9)	(4.4)	(4.3)	(2.6)	(2.0)	(3.8)	(1.4)	(1.0)	(1.4)	(1.7)
Abs.deviation (pp.)	−50	−41	−25	−37	−28	−25	−14	−22	−13	−2	−11	4	−12	−10	−8	−14	−9	−20
	(8.0)	(5.8)	(5.7)	(4.6)	(4.3)	(6.8)	(4.9)	(3.2)	(5.5)	(4.1)	(3.7)	(2.2)	(2.3)	(4.4)	(1.0)	(2.0)	(1.3)	(1.7)
Relative deviation (%)	−45	−44	−48	−45	−38	−47	−32	−38	−34	−3	−35	14	−54	−16	−40	−52	−25	−37
	(6.5)	(6.8)	(9.4)	(5.2)	(5.9)	(12.8)	(11.2)	(5.5)	(14.5)	(5.9)	(13.0)	(9.0)	(8.8)	(7.4)	(4.6)	(4.8)	(3.5)	(3.1)
Unrestriced GVAR																		
Act.sim.price increase (%)	109	93	65	88	83	74	52	69	42	71	33	29	26	66	21	34	40	60
CF.sim.price increase (%)	71	58	30	51	53	40	31	41	27	51	15	12	14	33	7	18	22	35
	(14.6)	(11.8)	(6.6)	(10.4)	(7.8)	(9.1)	(6.5)	(7.1)	(6.4)	(8.1)	(3.8)	(4.7)	(5.3)	(8.2)	(3.7)	(5.0)	(4.4)	(6.5)
Abs.deviation (pp.)	−38	−35	−35	−36	−30	−34	−22	−28	−15	−20	−18	−17	−13	−33	−15	−17	−18	−25
	(10.9)	(9.6)	(6.0)	(8.5)	(6.5)	(7.7)	(5.7)	(6.0)	(5.3)	(7.3)	(3.1)	(4.2)	(5.2)	(6.9)	(3.5)	(4.3)	(3.9)	(5.5)
Relative deviation (%)	−35	−38	−54	−41	−37	−46	−42	−40	−35	−28	−54	−58	−48	−50	−68	−49	−45	−42
	(9.4)	(9.5)	(8.4)	(9.0)	(7.5)	(9.6)	(9.0)	(8.0)	(11.8)	(9.8)	(9.1)	(10.6)	(12.5)	(9.9)	(10.9)	(9.4)	(8.4)	(8.3)
Restriced GVAR																		
Act.sim.price increase (%)	108	92	63	86	83	74	51	68	41	70	33	30	27	63	21	33	39	59
CF.sim.price increase (%)	75	64	42	59	52	41	35	43	25	47	20	19	14	44	9	19	24	39
	(10.8)	(8.3)	(5.6)	(7.8)	(6.1)	(6.7)	(5.2)	(5.2)	(6.8)	(4.2)	(3.0)	(3.6)	(5.2)	(4.7)	(2.7)	(2.3)	(2.9)	(4.4)
Abs.deviation (pp.)	−33	−28	−20	−27	−31	−33	−17	−26	−16	−23	−13	−11	−12	−19	−12	−14	−15	−20
	(9.3)	(7.7)	(5.0)	(7.1)	(5.4)	(5.7)	(5.0)	(4.6)	(5.6)	(4.3)	(2.7)	(3.3)	(5.2)	(3.8)	(2.6)	(2.6)	(2.8)	(4.1)
Relative deviation (%)	−31	−30	−33	−31	−38	−45	−32	−38	−39	−33	−40	−36	−46	−30	−57	−43	−38	−34
	(7.7)	(7.4)	(7.1)	(7.3)	(6.4)	(7.3)	(7.9)	(6.3)	(11.9)	(5.5)	(7.4)	(9.3)	(12.0)	(5.5)	(8.3)	(5.3)	(5.8)	(6.1)

Note: pp. are percentage points. Values in parentheses are standard errors calculated using bootstrap simulations of 200 replications. The *Abs. deviations* are defined as *CF. sim. price increase* minus *Act. sim. price increase*. *Relative deviations* are defined as *CF. sim. price increase* divided by *Act. sim. price increase* - 1.

E.2 The effects of financial deregulation

Figure E.2: Simulated prices in the CF scenario without ARMs (2000-07)



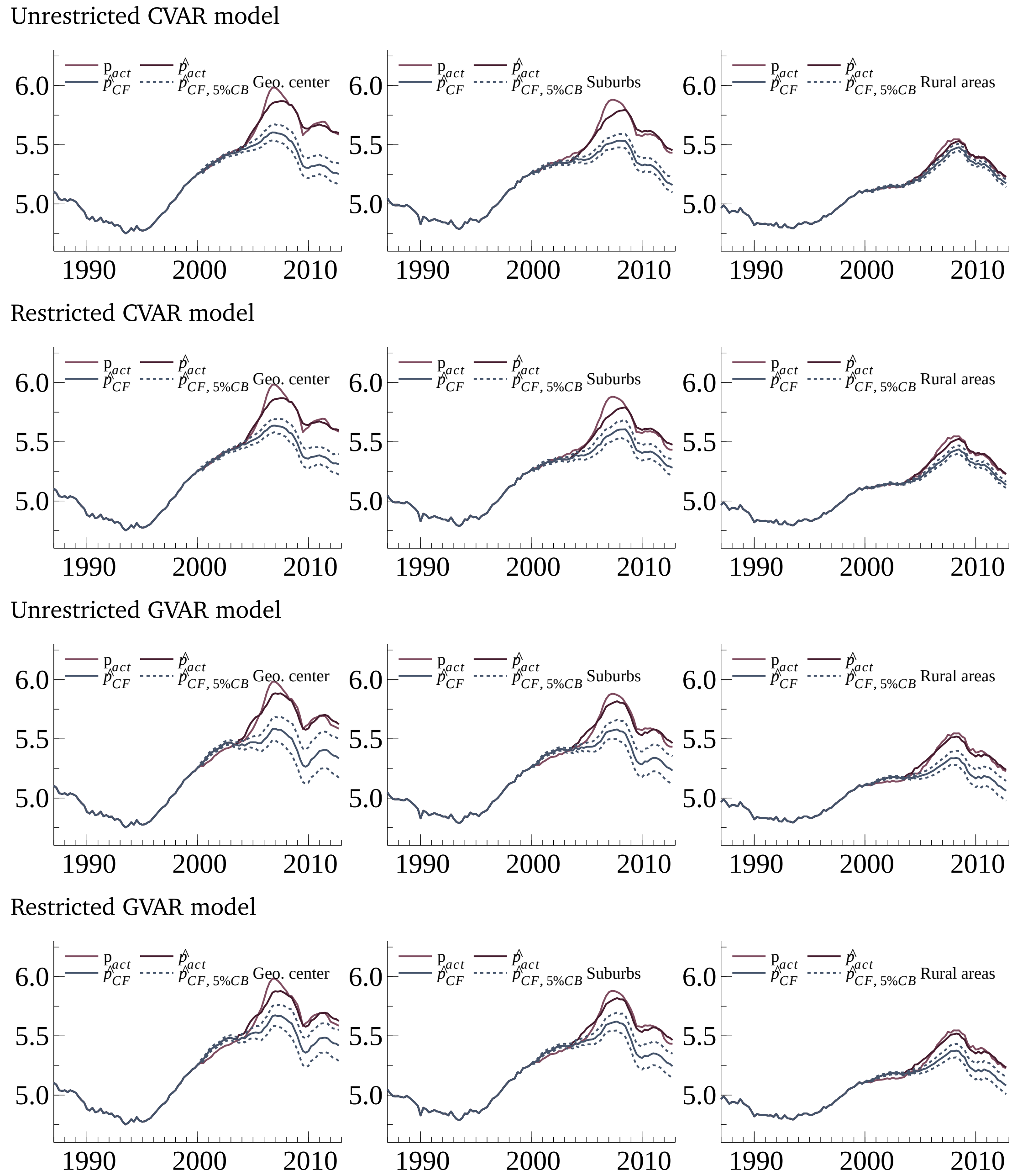
Note: Prices are simulated based on the CF scenario where the MFY includes a long 30-year mortgage rate throughout the sample, i.e. as if the ARM was never introduced (simulated from 2000q1 and onwards) (see Appendix D for details). The dotted lines are confidence bounds calculated using bootstrap simulations, 200 replications.

Table E.3: Price increases in the CF scenario without IOMs (2000-07)

	Geo. centers				Suburbs				Rural areas									
	Cph.c.	Cph.sub	Aarhus	Total	Fr.borg	Rosk.	Vejle	Total	Fyn	W. Zea.	N. Jut.	S. Jut.	Ribe	Storst.	Viborg	Ringk.	Total	National
Unrestricted CVAR																		
Act.sim.price increase (%)	111	90	56	83	81	55	44	60	38	68	32	27	21	60	20	27	36	55
CF.sim.price increase (%)	63	49	18	42	35	11	33	28	37	89	22	29	11	54	9	2	30	34
	(9.1)	(8.1)	(9.2)	(5.1)	(4.4)	(4.8)	(8.1)	(3.2)	(5.1)	(7.8)	(4.8)	(3.5)	(4.2)	(8.0)	(3.0)	(3.9)	(1.9)	(2.0)
Abs.deviation (pp.)	−47	−41	−37	−42	−45	−44	−12	−32	−1	20	−11	2	−10	−6	−11	−25	−6	−22
	(8.0)	(7.3)	(8.7)	(4.7)	(4.3)	(5.7)	(6.9)	(3.1)	(4.0)	(6.7)	(4.0)	(3.1)	(3.9)	(7.1)	(2.5)	(3.8)	(1.7)	(1.8)
Relative deviation (%)	−43	−46	−67	−50	−56	−80	−26	−53	−2	30	−33	8	−49	−10	−57	−93	−17	−40
	(7.1)	(8.4)	(15.9)	(5.7)	(5.4)	(10.4)	(15.9)	(5.4)	(10.9)	(9.8)	(13.3)	(10.9)	(15.1)	(11.9)	(12.9)	(14.5)	(4.6)	(3.4)
Restricted CVAR																		
Act.sim.price increase (%)	111	93	53	83	74	52	44	57	39	66	31	27	22	61	21	26	36	55
CF.sim.price increase (%)	63	49	31	46	41	30	29	34	26	64	19	31	7	54	9	7	26	34
	(7.3)	(8.0)	(4.5)	(4.1)	(4.8)	(5.4)	(8.2)	(4.0)	(7.7)	(5.8)	(4.5)	(3.7)	(3.2)	(5.6)	(1.5)	(1.7)	(1.8)	(1.7)
Abs.deviation (pp.)	−47	−45	−23	−37	−33	−22	−16	−24	−13	−2	−12	4	−15	−7	−12	−19	−10	−21
	(8.1)	(7.1)	(4.6)	(4.4)	(5.0)	(6.5)	(7.5)	(4.3)	(7.1)	(5.2)	(4.1)	(3.4)	(3.5)	(5.8)	(1.4)	(2.3)	(1.6)	(1.6)
Relative deviation (%)	−43	−48	−43	−44	−45	−42	−35	−41	−33	−3	−38	16	−69	−12	−57	−72	−29	−38
	(6.5)	(8.2)	(7.9)	(5.0)	(6.6)	(11.8)	(17.1)	(7.5)	(18.7)	(7.5)	(14.1)	(13.7)	(13.3)	(9.8)	(6.2)	(6.7)	(4.6)	(3.1)
Unrestriced GVAR																		
Act.sim.price increase (%)	109	93	65	88	83	74	52	69	42	71	33	29	26	66	21	34	40	60
CF.sim.price increase (%)	54	46	21	39	45	34	26	35	24	49	11	8	12	29	4	15	19	28
	(10.9)	(9.1)	(5.5)	(7.8)	(5.8)	(6.7)	(5.2)	(5.1)	(6.0)	(6.9)	(3.5)	(3.9)	(4.3)	(6.1)	(2.9)	(3.9)	(3.2)	(4.6)
Abs.deviation (pp.)	−55	−47	−44	−48	−38	−41	−26	−34	−17	−22	−22	−21	−14	−37	−17	−19	−21	−32
	(9.1)	(8.1)	(5.2)	(7.0)	(5.2)	(6.2)	(4.8)	(4.6)	(5.0)	(6.8)	(2.8)	(3.8)	(4.4)	(5.7)	(2.7)	(3.3)	(2.9)	(4.2)
Relative deviation (%)	−51	−51	−68	−55	−46	−55	−50	−49	−42	−31	−67	−73	−53	−56	−80	−56	−53	−53
	(7.9)	(8.1)	(7.5)	(7.5)	(5.9)	(7.6)	(7.6)	(6.1)	(11.2)	(9.2)	(8.4)	(9.4)	(10.6)	(8.1)	(8.8)	(7.6)	(6.3)	(6.3)
Restriced GVAR																		
Act.sim.price increase (%)	108	92	63	86	83	74	51	68	41	70	33	30	27	63	21	33	39	59
CF.sim.price increase (%)	64	57	37	52	49	41	32	40	24	45	18	19	13	43	8	15	23	35
	(10.1)	(7.5)	(5.7)	(7.1)	(5.5)	(5.9)	(4.1)	(4.0)	(6.5)	(3.3)	(2.8)	(3.6)	(4.7)	(3.8)	(3.0)	(2.2)	(2.2)	(3.6)
Abs.deviation (pp.)	−44	−35	−25	−34	−34	−33	−20	−28	−18	−25	−15	−12	−14	−20	−13	−18	−17	−24
	(9.3)	(7.5)	(5.1)	(6.9)	(5.2)	(5.4)	(4.2)	(3.9)	(5.6)	(3.9)	(2.6)	(3.4)	(5.0)	(3.5)	(2.7)	(2.5)	(2.4)	(3.5)
Relative deviation (%)	−41	−39	−41	−40	−41	−45	−38	−41	−43	−36	−46	−39	−52	−31	−62	−54	−42	−41
	(7.7)	(7.1)	(7.3)	(7.1)	(6.0)	(6.6)	(6.5)	(5.0)	(11.7)	(4.9)	(7.2)	(9.7)	(11.7)	(4.8)	(9.1)	(5.0)	(4.8)	(5.1)

Note: pp. are percentage points. Values in parentheses are standard errors calculated using bootstrap simulations of 200 replications. The *Abs. deviations* are defined as *CF. sim. price increase* minus *Act. sim. price increase*. *Relative deviations* are defined as *CF. sim. price increase* divided by *Act. sim. price increase* - 1.

Figure E.3: Simulated prices in the CF scenario without IOMs (2000-07)



Note: Prices are simulated based on the CF scenario where the MFY includes the amortizations on a 30-year annuity throughout the sample, i.e. as if the IOMs were never introduced (simulated from 2000q1 and onwards) (see Appendix D for details). The dotted lines are confidence bounds calculated using bootstrap simulations, 200 replications.

Table E.4: Price increases in the CF scenario with a ”neutral” monetary policy (2000-07)

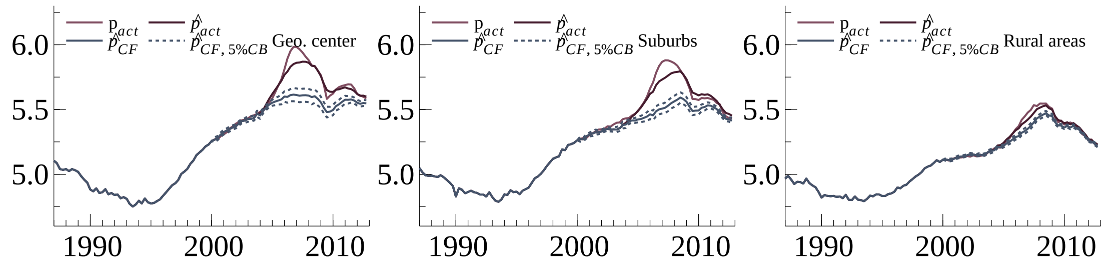
	Geo. centers				Suburbs				Rural areas									
	Cph.c.	Cph.sub	Aarhus	Total	Fr.borg	Rosk.	Vejle	Total	Fyn	W. Zea.	N. Jut.	S. Jut.	Ribe	Storst.	Viborg	Ringk.	Total	National
Unrestricted CVAR																		
Act.sim.price increase (%)	111	90	56	83	81	55	44	60	38	68	32	27	21	60	20	27	36	55
CF.sim.price increase (%)	65	53	17	43	35	14	29	28	34	71	19	25	10	49	12	3	27	32
	(7.1)	(6.3)	(6.2)	(3.7)	(3.4)	(4.3)	(5.2)	(2.4)	(3.5)	(5.5)	(3.5)	(2.9)	(3.4)	(5.6)	(2.4)	(3.1)	(1.3)	(1.4)
Abs.deviation (pp.)	−45	−36	−39	−40	−45	−41	−15	−32	−4	2	−14	−2	−12	−11	−8	−23	−9	−23
	(7.1)	(6.2)	(6.2)	(3.7)	(4.0)	(5.5)	(4.5)	(2.6)	(2.9)	(5.0)	(2.7)	(2.4)	(3.3)	(5.0)	(2.1)	(3.3)	(1.2)	(1.4)
Relative deviation (%)	−41	−41	−70	−49	−56	−74	−33	−54	−10	3	−42	−7	−55	−18	−40	−87	−26	−42
	(6.1)	(6.9)	(11.1)	(4.4)	(4.7)	(9.8)	(10.3)	(4.3)	(7.6)	(7.4)	(8.9)	(8.7)	(12.6)	(8.3)	(10.0)	(11.9)	(3.2)	(2.5)
Restricted CVAR																		
Act.sim.price increase (%)	111	93	53	83	74	52	44	57	39	66	31	27	22	61	21	26	36	55
CF.sim.price increase (%)	65	48	31	47	38	29	26	31	25	58	19	28	7	52	8	7	25	33
	(5.7)	(4.8)	(3.4)	(3.0)	(2.2)	(4.9)	(4.6)	(2.6)	(5.7)	(4.8)	(3.1)	(3.2)	(2.2)	(4.7)	(2.1)	(1.4)	(1.3)	(1.1)
Abs.deviation (pp.)	−45	−45	−22	−36	−37	−24	−18	−26	−15	−8	−12	1	−15	−9	−13	−19	−12	−22
	(5.8)	(5.5)	(4.4)	(3.7)	(2.8)	(6.1)	(4.1)	(3.1)	(5.3)	(4.7)	(2.2)	(3.0)	(2.6)	(5.1)	(1.8)	(2.4)	(1.1)	(1.2)
Relative deviation (%)	−41	−48	−42	−44	−49	−45	−40	−45	−37	−12	−37	5	−69	−15	−62	−72	−32	−40
	(5.1)	(5.8)	(6.9)	(4.0)	(3.3)	(11.1)	(9.3)	(5.1)	(13.5)	(6.7)	(7.8)	(12.4)	(9.3)	(8.4)	(8.8)	(6.9)	(3.1)	(2.1)
Unrestriced GVAR																		
Act.sim.price increase (%)	109	93	65	88	83	74	52	69	42	71	33	29	26	66	21	34	40	60
CF.sim.price increase (%)	66	61	29	51	57	48	34	46	28	58	16	15	14	46	10	19	25	37
	(8.4)	(7.1)	(4.1)	(5.8)	(4.8)	(5.6)	(3.9)	(4.1)	(4.5)	(5.0)	(2.7)	(2.9)	(3.7)	(4.8)	(2.2)	(3.1)	(2.4)	(3.5)
Abs.deviation (pp.)	−43	−33	−36	−37	−26	−27	−18	−23	−14	−13	−17	−14	−12	−20	−11	−16	−15	−23
	(7.4)	(6.8)	(3.9)	(5.5)	(4.6)	(5.3)	(3.8)	(3.9)	(3.8)	(4.8)	(2.1)	(2.7)	(3.8)	(4.4)	(2.1)	(2.6)	(2.2)	(3.3)
Relative deviation (%)	−40	−35	−55	−42	−31	−36	−34	−33	−33	−18	−52	−48	−47	−30	−52	−45	−37	−38
	(6.4)	(6.7)	(5.6)	(5.8)	(5.2)	(6.5)	(5.9)	(5.1)	(8.4)	(6.5)	(6.3)	(6.6)	(9.2)	(6.3)	(6.6)	(6.0)	(4.8)	(4.9)
Restriced GVAR																		
Act.sim.price increase (%)	108	92	63	86	83	74	51	68	41	70	33	30	27	63	21	33	39	59
CF.sim.price increase (%)	72	67	40	58	59	49	35	47	28	54	22	23	15	55	12	18	28	41
	(7.6)	(5.8)	(3.9)	(5.3)	(4.4)	(4.8)	(3.2)	(3.2)	(4.7)	(2.8)	(2.0)	(2.6)	(4.4)	(3.4)	(2.2)	(1.9)	(1.6)	(2.7)
Abs.deviation (pp.)	−36	−26	−23	−28	−24	−24	−17	−21	−13	−16	−11	−7	−12	−8	−9	−16	−12	−18
	(7.0)	(6.2)	(3.7)	(5.3)	(4.3)	(3.9)	(3.6)	(3.2)	(3.9)	(2.9)	(1.7)	(2.3)	(4.5)	(2.8)	(2.2)	(2.2)	(1.7)	(2.7)
Relative deviation (%)	−34	−28	−36	−32	−29	−33	−32	−31	−33	−23	−34	−23	−43	−13	−44	−48	−30	−31
	(6.0)	(5.9)	(5.2)	(5.5)	(4.9)	(4.9)	(5.6)	(4.2)	(8.5)	(3.8)	(4.6)	(6.4)	(10.9)	(3.9)	(7.0)	(4.5)	(3.5)	(3.9)

Note: pp. are percentage points. Values in parentheses are standard errors calculated using bootstrap simulations of 200 replications. The *Abs. deviations* are defined as *CF. sim. price increase* minus *Act. sim. price increase*. *Relative deviations* are defined as *CF. sim. price increase* divided by *Act. sim. price increase* - 1.

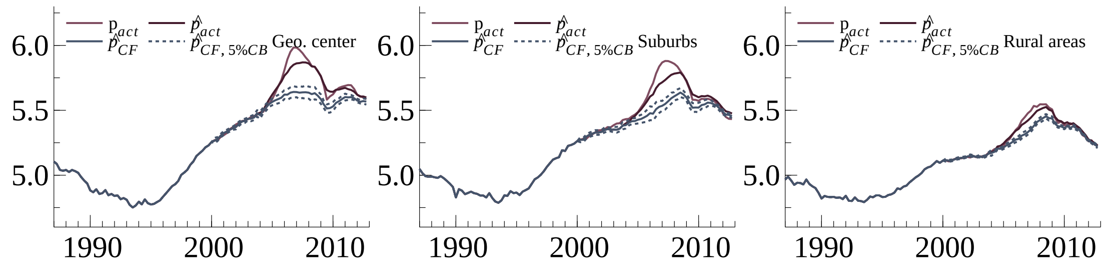
E.3 The effects of monetary and fiscal policy

Figure E.4: Simulated prices in the CF scenario with a ”neutral” monetary policy (2000-07)

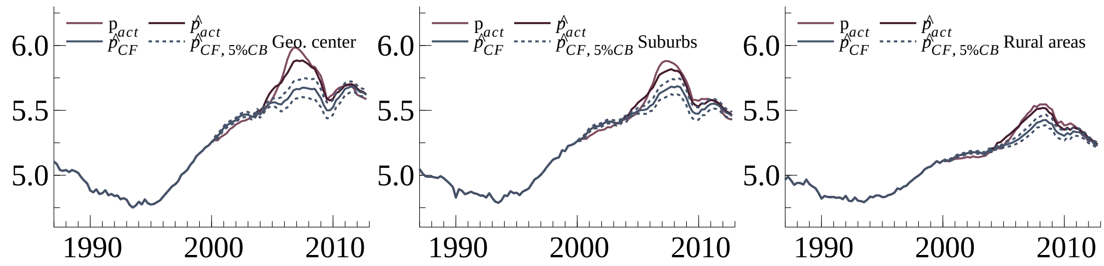
Unrestricted CVAR model



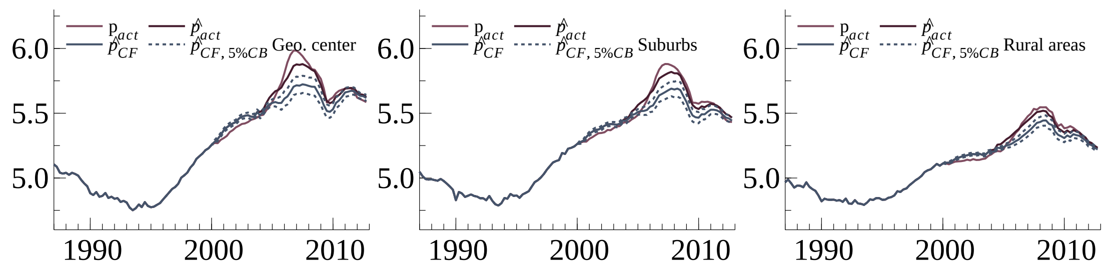
Restricted CVAR model



Unrestricted GVAR model



Restricted GVAR model



Note: Prices are simulated based on the CF scenario where the monetary policy MFY and UC in the models) followed the ECB Taylor-rule applied to Danish conditions from 2004-07 (simulated from 2000q1 and onwards) (see Appendix D for details). The dotted lines are confidence bounds calculated using bootstrap simulations, 200 replications.

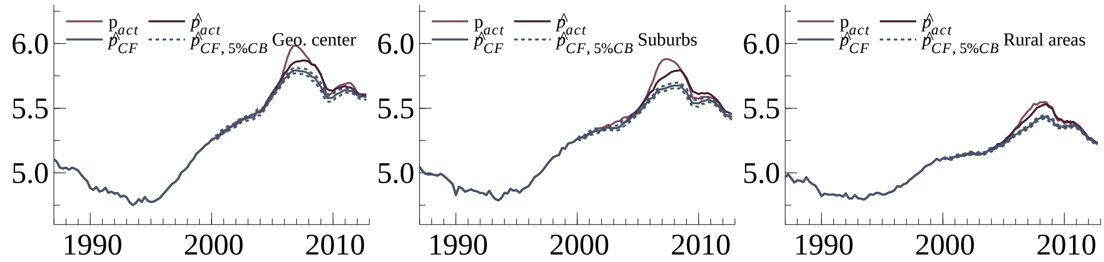
Table E.5: Price increases in the CF scenario with a ”neutral” fiscal policy (2000-07)

	Geo. centers				Suburbs				Rural areas									
	Cph.c.	Cph.sub	Aarhus	Total	Fr.borg	Rosk.	Vejle	Total	Fyn	W. Zea.	N. Jut.	S. Jut.	Ribe	Storst.	Viborg	Ringk.	Total	National
Unrestricted CVAR																		
Act.sim.price increase (%)	111	90	56	83	81	55	44	60	38	68	32	27	21	60	20	27	36	55
CF.sim.price increase (%)	94	75	49	71	64	41	35	47	27	52	23	20	13	54	13	19	27	45
	(5.2)	(3.2)	(3.3)	(2.1)	(3.0)	(2.8)	(2.9)	(1.7)	(1.7)	(2.8)	(2.5)	(1.6)	(1.6)	(3.1)	(1.6)	(1.9)	(0.9)	(0.8)
Abs.deviation (pp.)	−17	−15	−7	−12	−17	−14	−9	−13	−11	−16	−10	−8	−9	−6	−7	−8	−9	−11
	(2.7)	(1.7)	(2.2)	(1.3)	(1.3)	(1.3)	(1.8)	(0.8)	(0.9)	(2.0)	(1.6)	(1.1)	(1.3)	(1.5)	(0.9)	(1.4)	(0.5)	(0.5)
Relative deviation (%)	−15	−16	−12	−15	−21	−26	−20	−22	−29	−23	−30	−28	−41	−10	−34	−29	−26	−20
	(2.6)	(2.0)	(4.0)	(1.6)	(1.8)	(3.1)	(4.4)	(1.7)	(2.5)	(2.9)	(5.1)	(3.7)	(5.4)	(2.7)	(4.8)	(5.2)	(1.4)	(0.9)
Restricted CVAR																		
Act.sim.price increase (%)	111	93	53	83	74	52	44	57	39	66	31	27	22	61	21	26	36	55
CF.sim.price increase (%)	94	81	46	72	57	41	36	45	28	53	21	18	14	56	13	19	27	44
	(2.6)	(2.7)	(1.7)	(1.4)	(2.4)	(3.2)	(2.6)	(1.9)	(1.8)	(2.3)	(2.2)	(1.4)	(1.2)	(2.0)	(1.2)	(2.0)	(0.7)	(0.7)
Abs.deviation (pp.)	−17	−12	−7	−11	−17	−11	−9	−12	−11	−14	−10	−9	−8	−5	−7	−8	−9	−11
	(2.7)	(1.7)	(1.8)	(1.2)	(1.1)	(1.4)	(1.2)	(0.6)	(0.8)	(1.5)	(1.5)	(1.4)	(1.5)	(1.4)	(0.5)	(0.7)	(0.3)	(0.4)
Relative deviation (%)	−15	−13	−14	−14	−23	−22	−20	−22	−29	−21	−31	−32	−36	−8	−35	−29	−25	−19
	(2.2)	(1.9)	(2.9)	(1.3)	(1.5)	(3.7)	(2.9)	(1.6)	(1.8)	(2.2)	(5.2)	(5.2)	(5.8)	(2.3)	(2.5)	(3.4)	(1.0)	(0.8)
Unrestriced GVAR																		
Act.sim.price increase (%)	109	93	65	88	83	74	52	69	42	71	33	29	26	66	21	34	40	60
CF.sim.price increase (%)	88	76	53	71	65	60	39	54	29	56	24	22	17	53	14	26	29	47
	(3.8)	(2.8)	(1.8)	(2.1)	(2.3)	(2.8)	(1.4)	(1.4)	(1.4)	(1.9)	(1.7)	(1.2)	(1.2)	(2.1)	(1.2)	(1.4)	(0.7)	(1.0)
Abs.deviation (pp.)	−21	−17	−12	−16	−18	−14	−13	−15	−13	−15	−10	−7	−9	−13	−7	−9	−11	−13
	(2.1)	(1.7)	(1.3)	(1.4)	(1.2)	(1.2)	(1.2)	(0.9)	(0.9)	(1.3)	(0.9)	(0.7)	(1.2)	(1.3)	(0.8)	(1.0)	(0.5)	(0.8)
Relative deviation (%)	−19	−18	−18	−19	−22	−19	−25	−22	−31	−22	−29	−25	−36	−19	−34	−25	−26	−22
	(2.0)	(1.7)	(1.8)	(1.6)	(1.5)	(1.6)	(1.8)	(1.2)	(2.0)	(1.7)	(2.4)	(1.6)	(3.0)	(1.9)	(2.6)	(2.0)	(1.1)	(1.2)
Restriced GVAR																		
Act.sim.price increase (%)	108	92	63	86	83	74	51	68	41	70	33	30	27	63	21	33	39	59
CF.sim.price increase (%)	88	76	51	71	65	58	40	54	29	55	23	22	19	52	14	25	29	47
	(3.4)	(1.8)	(1.5)	(1.6)	(1.9)	(3.1)	(1.0)	(1.3)	(1.3)	(1.9)	(1.4)	(1.2)	(1.4)	(2.1)	(1.0)	(1.0)	(0.6)	(0.8)
Abs.deviation (pp.)	−20	−16	−11	−16	−18	−16	−11	−15	−12	−16	−11	−8	−8	−11	−7	−9	−10	−13
	(2.5)	(1.7)	(1.1)	(1.4)	(1.5)	(1.3)	(0.8)	(1.0)	(0.9)	(1.4)	(0.9)	(0.5)	(1.2)	(1.4)	(0.6)	(0.9)	(0.5)	(0.8)
Relative deviation (%)	−19	−18	−18	−18	−22	−22	−22	−22	−29	−22	−33	−28	−30	−18	−32	−26	−27	−22
	(2.1)	(1.5)	(1.6)	(1.4)	(1.5)	(1.7)	(1.3)	(1.1)	(1.8)	(1.7)	(2.3)	(1.5)	(3.1)	(2.0)	(2.0)	(1.8)	(1.0)	(1.1)

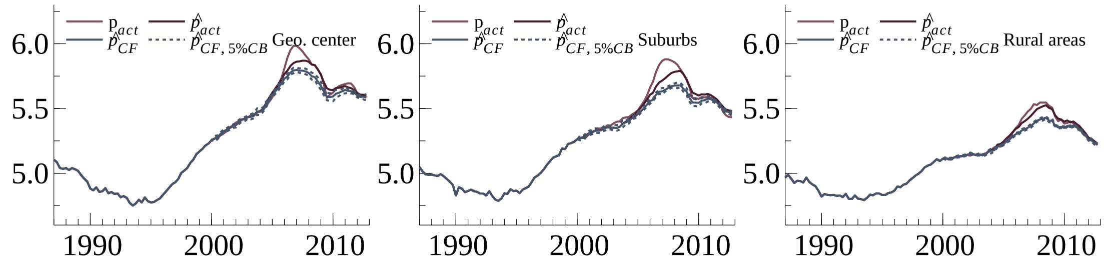
Note: pp. are percentage points. Values in parentheses are standard errors calculated using bootstrap simulations of 200 replications. The *Abs. deviations* are defined as *CF. sim. price increase* minus *Act. sim. price increase*. *Relative deviations* are defined as *CF. sim. price increase* divided by *Act. sim. price increase* - 1.

Figure E.5: Simulated prices in the CF scenario with a ”neutral” fiscal policy (2000-07)

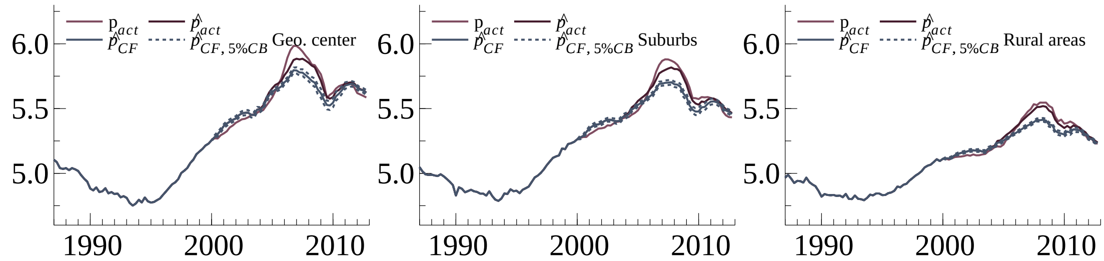
Unrestricted CVAR model



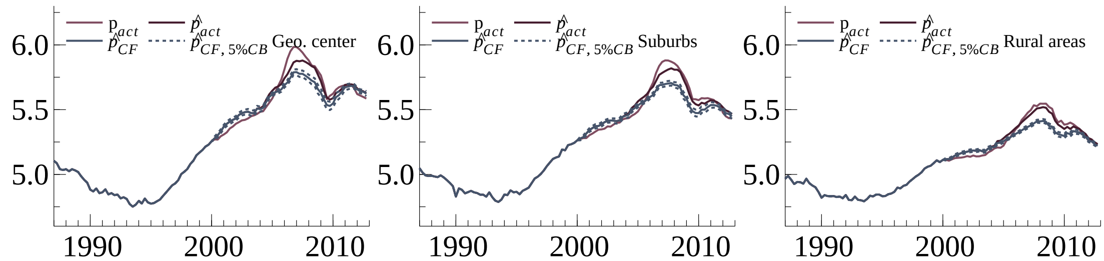
Restricted CVAR model



Unrestricted GVAR model



Restricted GVAR model



Note: Prices are simulated based on the CF scenario where the fiscal policy (u and y in the models) followed an output-gap stabilizing rule from 2004-07 (simulated from 2000q1 and onwards) (see Appendix D for details). The dotted lines are confidence bounds calculated using bootstrap simulations, 200 replications.

Table E.6: Price increases in the CF scenario without the tax freeze policy (2000-07)

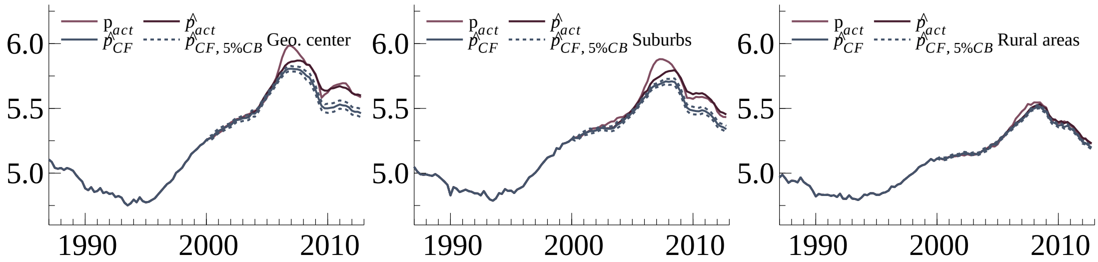
	Geo. centers				Suburbs				Rural areas									
	Cph.c.	Cph.sub	Aarhus	Total	Fr.borg	Rosk.	Vejle	Total	Fyn	W. Zea.	N. Jut.	S. Jut.	Ribe	Storst.	Viborg	Ringk.	Total	National
Unrestricted CVAR																		
Act.sim.price increase (%)	111	90	56	83	81	55	44	60	38	68	32	27	21	60	20	27	36	55
CF.sim.price increase (%)	98 (4.2)	80 (2.9)	48 (2.3)	73 (1.7)	66 (2.3)	45 (1.9)	42 (1.9)	52 (1.2)	38 (1.6)	67 (2.6)	30 (2.3)	27 (1.7)	20 (1.0)	58 (2.4)	19 (1.3)	24 (1.3)	35 (0.8)	50 (0.7)
Abs.deviation (pp.)	−13 (3.0)	−10 (2.2)	−8 (1.3)	−10 (1.2)	−14 (1.7)	−10 (1.4)	−2 (0.7)	−8 (0.7)	0 (0.5)	−2 (1.6)	−2 (0.4)	0 (0.7)	−1 (0.5)	−3 (1.0)	−1 (0.2)	−2 (0.4)	−1 (0.2)	−5 (0.4)
Relative deviation (%)	−12 (2.6)	−11 (2.4)	−14 (2.3)	−12 (1.4)	−18 (2.0)	−18 (2.7)	−5 (1.7)	−14 (1.2)	0 (1.2)	−3 (2.4)	−7 (1.4)	−1 (2.4)	−7 (1.8)	−4 (1.7)	−4 (1.2)	−9 (1.4)	−4 (0.6)	−9 (0.7)
Restricted CVAR																		
Act.sim.price increase (%)	111	93	53	83	74	52	44	57	39	66	31	27	22	61	21	26	36	55
CF.sim.price increase (%)	98 (3.7)	80 (1.9)	49 (1.5)	74 (1.3)	63 (1.9)	46 (1.6)	42 (2.0)	51 (1.0)	38 (2.0)	63 (2.4)	29 (1.9)	27 (1.5)	20 (0.5)	60 (1.6)	19 (1.3)	24 (1.9)	35 (0.7)	50 (0.6)
Abs.deviation (pp.)	−13 (2.2)	−13 (2.1)	−4 (1.1)	−9 (1.2)	−12 (1.2)	−6 (1.5)	−3 (0.8)	−7 (0.9)	−1 (0.7)	−3 (1.8)	−2 (0.3)	0 (0.7)	−2 (0.4)	−1 (0.9)	−1 (0.2)	−2 (0.3)	−2 (0.2)	−5 (0.4)
Relative deviation (%)	−12 (2.1)	−14 (2.2)	−7 (1.7)	−11 (1.4)	−16 (1.4)	−11 (2.7)	−6 (1.9)	−12 (1.5)	−4 (1.7)	−5 (2.6)	−5 (1.0)	1 (2.9)	−8 (1.4)	−2 (1.5)	−6 (1.1)	−8 (1.0)	−4 (0.7)	−9 (0.7)
Unrestriced GVAR																		
Act.sim.price increase (%)	109	93	65	88	83	74	52	69	42	71	33	29	26	66	21	34	40	60
CF.sim.price increase (%)	98 (3.9)	87 (3.0)	57 (1.8)	79 (2.3)	77 (2.3)	69 (2.8)	49 (1.4)	64 (1.6)	39 (1.5)	70 (2.0)	30 (1.7)	26 (1.4)	24 (1.1)	64 (2.1)	20 (1.0)	32 (1.5)	37 (0.9)	56 (1.2)
Abs.deviation (pp.)	−11 (2.7)	−7 (2.3)	−7 (1.1)	−8 (1.8)	−6 (1.6)	−6 (1.5)	−3 (0.9)	−5 (1.2)	−2 (0.8)	−1 (1.3)	−3 (0.4)	−4 (0.7)	−2 (0.6)	−2 (1.2)	−2 (0.4)	−3 (0.5)	−2 (0.5)	−5 (1.0)
Relative deviation (%)	−10 (2.3)	−7 (2.2)	−11 (1.5)	−9 (1.9)	−7 (1.8)	−7 (1.9)	−6 (1.4)	−7 (1.5)	−5 (1.8)	−2 (1.7)	−9 (1.3)	−12 (1.8)	−8 (1.5)	−3 (1.6)	−7 (1.2)	−8 (1.2)	−6 (1.2)	−8 (1.5)
Restriced GVAR																		
Act.sim.price increase (%)	108	92	63	86	83	74	51	68	41	70	33	30	27	63	21	33	39	59
CF.sim.price increase (%)	98 (4.0)	86 (2.0)	57 (1.5)	79 (2.0)	77 (2.3)	68 (3.2)	48 (0.8)	64 (1.4)	39 (1.4)	67 (2.0)	31 (1.5)	28 (1.4)	25 (1.0)	62 (2.1)	20 (0.9)	31 (1.0)	37 (0.7)	55 (1.0)
Abs.deviation (pp.)	−10 (2.4)	−6 (1.9)	−5 (1.0)	−7 (1.6)	−6 (1.5)	−6 (1.1)	−3 (0.7)	−5 (0.9)	−2 (0.7)	−3 (1.1)	−2 (0.4)	−2 (0.6)	−2 (0.6)	−1 (0.9)	−1 (0.3)	−3 (0.4)	−2 (0.4)	−4 (0.7)
Relative deviation (%)	−9 (2.1)	−7 (1.9)	−8 (1.4)	−8 (1.7)	−7 (1.7)	−8 (1.4)	−7 (1.2)	−7 (1.2)	−6 (1.5)	−5 (1.4)	−7 (1.0)	−6 (1.6)	−7 (1.6)	−1 (1.3)	−7 (0.8)	−8 (0.8)	−5 (0.8)	−7 (1.1)

Note: pp. are percentage points. Values in parentheses are standard errors calculated using bootstrap simulations of 200 replications. The *Abs. deviations* are defined as *CF. sim. price increase* minus *Act. sim. price increase*. *Relative deviations* are defined as *CF. sim. price increase* divided by *Act. sim. price increase* - 1.

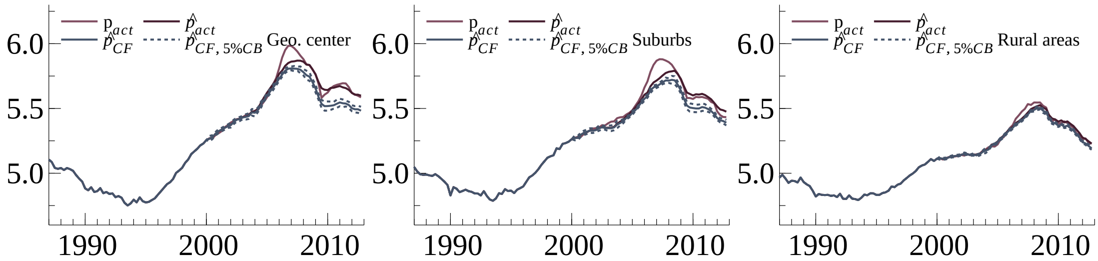
E.4 The effects of the tax freeze policy from 2002

Figure E.6: Simulated prices in the CF scenario without tax freeze polity (2000-07)

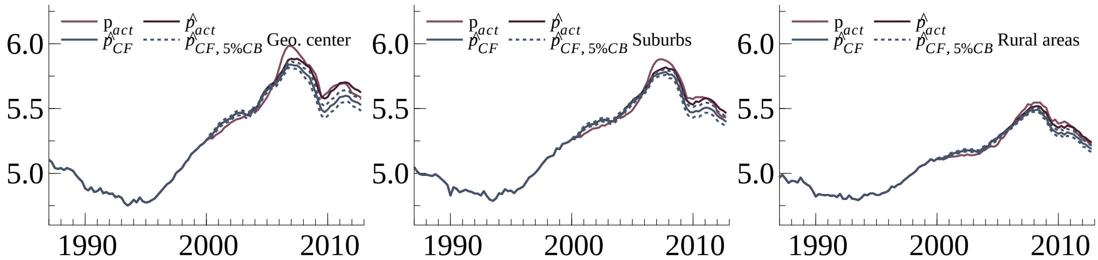
Unrestricted CVAR model



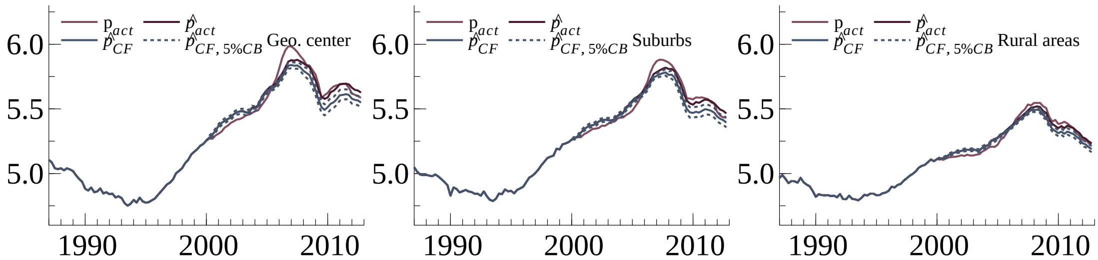
Restricted CVAR model



Unrestricted GVAR model



Restricted GVAR model



Note: Prices are simulated based on the CF scenario where the property tax rules of 2001 were keep throughout the sample period (affecting MFY and UC in the models, simulated from 2000q1 and onwards) (see Appendix D for details). The dotted lines are confidence bounds calculated using bootstrap simulations, 200 replications.