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The ripple effect and the linguistic border in Belgium: a country divided?

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Abstract

A large literature has emerged, especially in the UK, that investigates regional convergence of house prices. Many authors have found regional house prices to be converging in the long-run and exhibit a distinct spatial pattern over time, which has become known as the *ripple effect hypothesis*. In this paper we examine the validity of the ripple effect hypothesis for Belgium and are particularly interested in the role of the linguistic border in the spatial and temporal propagation of shocks in a dynamic system. We extend the model that was recently proposed by Holly *et al.* (2011) to cope with the unique federal structure of Belgium and use data at the level of the judicial districts ($N = 20$) for an extensive time period (1973Q1-2011Q3, $T = 155$). We show that the linguistic border plays an ambiguous role. The results indicate that almost all regional house prices are converging in the long-run, which implies that regional markets in Belgium are integrated. We furthermore show that house prices in regions which are located along the north-south axis in Belgium, which constitutes the economic spine of Belgium, converge more quickly with respect to house prices in the dominant region, Antwerp. This result suggests that the linguistic border plays no significant role in the house price diffusion process. After this initial error correction mechanism, however, the convergence process follows a distinct linguistic pattern (east-west axis) where regions converge only with respect to neighboring regions that are located within the same linguistic region. Moreover, short-run spatial spill-overs are significant for nearly all neighboring regions that lie within the same linguistic area, but nearly nonexistent for neighboring regions across the linguistic border. Finally, we provide evidence for the *ripple effect hypothesis* in Belgium.

1 Introduction

A large literature has emerged, especially in the United Kingdom, that investigates regional convergence of house prices and many authors have found regional house prices to be converging in the long run and exhibit a distinct spatial pattern over time, rising first in a cyclical upswing in the south-east and, then, spreading out over the rest of the country (Meen, 1999). This pattern has often been referred to as the *ripple effect hypothesis*. In the current paper we investigate the ripple effect hypothesis for Belgium using an extended version of a model that was recently proposed by Holly *et al.* (2011). We extend the existing model to cope with the unique federal structure of Belgium[1], which is home to two main linguistic groups, and investigate what role the linguistic border plays in the spatial and temporal diffusion of house prices. Convergence and diffusion patterns of regional house prices have been studied in many occasions because of their importance for regional labor markets and the regional distribution of wealth and assets. Efficient functioning of the economy, for example, may be impaired if labor mobility is hampered by the high cost of housing in certain areas (Alexander and Barrow, 1994). Regional differences in increases in house prices furthermore imply changes in the regional distribution of wealth, since housing is the main form of asset for many households. Additionally, regional differences in house price changes imply that households benefit unequally from having access to tax advantages, since housing is a tax-favored form of saving due to the absence of taxes on capital gains (Alexander and Barrow, 1994).

In the current study we investigate the role of the linguistic border in spatial and temporal diffusion patterns of regional house prices. Theoretically, we contribute to the existing literature by extending the model proposed by Holly *et al.* (2011) to explicitly allow for a discontinuity. Empirically, we contribute to the border effects literature and investigate the role of linguistic differences versus economic ties. We use mix-adjusted house price transaction data at the municipal level and aggregate these into 20 predefined regions, which largely correspond with the judicial districts in Belgium.[2] In table 1 an overview of the different regions, their abbreviations and their respective neighbors is provided. Since we have transaction data aggregated at the municipal level at our disposal, we can control for border effects by eliminating the data from municipalities that are located along the borders with the Netherlands, France, Germany and Luxembourg.[3]

Our results suggest that the linguistic border plays an ambiguous role in the spatial and temporal diffusion of shocks to house prices. Convergence with respect to shocks in a dominant region, Antwerp, initially occurs along the centrally located north-south axis, which constitutes the eco-

[1]Belgium is home to two main linguistic groups, the northern Dutch-speaking region of Flanders and the southern French-speaking region Wallonia. The Brussels Capital Region, officially bilingual, is a mostly French-speaking enclave within the Flemish Region.

[2]Belgium has 27 judicial districts. In 2012, however, an agreement was made which will bring back the number of judicial districts to 12.

[3]Unlike the UK, Belgium has 4 neighboring countries. We only eliminate municipalities that are adjacent to a neighboring country.

nomic spine of Belgium, and thus goes across the linguistic border. Thereafter, however, the convergence process follows a distinct linguistic pattern and occurs along the east-west axis, whereby regions only display error correcting behavior with respect to neighboring regions that lie within the same linguistic area. After an initial shock in the dominant region, regions which are economically more close to the dominant region first converge, where the remaining regions converge within their linguistic areas. Furthermore, short-run dynamics also display a distinct linguistic pattern, where spill-over effects only are present *within* each linguistic area.

Table 1: Regions and their neighbors

Regions (Abbrev.)	Language (province)	Neighbors
Antwerp (ANT)	Dutch (Antwerp)	MEC, TUR, DEN
Mechelen (MEC)	Dutch (Antwerp)	ANT, TUR, BRX, LEU, DEN
Turnhout (TUR)	Dutch (Antwerp)	ANT, MEC, LEU, HAS
Brussels (BRX)	Bilingual (Flemish Brabant)	MEC, LEU, *NIV*, DEN, OUD, *TOU*
Leuven (LEU)	Dutch (Flemish Brabant)	MEC, TUR, BRX, *NIV*, *LIE*, HAS
Nivelles (NIV)	French (Walloon Brabant)	*BRX*, *LEU*, CHA, TOU, LIE, NAM
Bruges (BRU)	Dutch (West Flanders)	KOR, VEU, GHE
Kortrijk (KOR)	Dutch (West Flanders)	BRU, VEU, GHE, OUD, *TOU*
Veurne (VEU)	Dutch (West Flanders)	BRU, KOR
Dendermonde (DEN)	Dutch (East Flanders)	ANT, MEC, BRX, GHE, OUD
Ghent (GHE)	Dutch (East Flanders)	BRU, KOR, DEN, OUD
Oudenaarde (OUD)	Dutch (East Flanders)	BRX, KOR, DEN, GHE, *TOU*
Charleroi (CHA)	French (Hainaut)	NIV, TOU, DIN, NAM
Tournai (TOU)	French (Hainaut)	*BRX*, *KOR*, *OUD*, CHA
Liège (LIE)	French (Liège)	*LEU*, NIV, VER, *HAS*, ARL, DIN, NAM
Verviers (VER)	French (Liège)	LIE, ARL
Hasselt (HAS)	Dutch (Limburg)	TUR, LEU, *LIE*
Arlon (ARL)	French (Luxembourg)	LIE, VER, DIN
Dinant (DIN)	French (Namur)	CHA, LIE, ARL, NAM
Namur (NAM)	French (Namur)	NIV, CHA, LUI, DIN

Notes: The neighbors displayed in italics are located on the opposite side of the linguistic border. Note that despite the Brussels Capital Region is geographically fully enclosed by the Flemish provice of Flemish Brabant, it is officially a bilingual region and is thus considered to be both French- and Dutch-speaking.

The rest of the paper is set out as follows: in section 2 we provide an overview of the literature on long-run convergence of regional house prices and spatio-temporal dynamics in house price patterns. In the third section we propose the methodology. We first discuss the recently developed pair-wise approach (Pesaran, 2007) that is used to assess whether house prices are converging in the long-run. Next, we discuss the spatial weights matrices that are used to generate the spatially lagged variables and the empirical model. We furthermore lay out a method, which is related to the concept of long-run causality (Granger and Lin, 1995), to determine which region is a valid candidate for the dominant region and discuss the exogeneity tests that are used in the empirical analysis. Finally, we elaborate on the Generalized spatio-temporal Impulse Response Functions (GIRF), which are a useful tool to help us interpreting the results. In section 4, we report the estimation results and interpret them using the aforementioned GIRF's. Finally, section 5 concludes.

2 Literature

Many researchers, especially in the UK, have studied spatial and temporal patterns in regional house prices. A number of authors, such as MacDonald and Taylor (1993), Alexander and Barrow (1994), Holmes and Grimes (2008) and Abbott and De Vita (2013) have studied the long-run relationships among regional house prices, where these and other authors, such as Giussani and Hadjimatheou (1991), Ashworth and Parker (1997), Meen (1999) and Holly *et al.* (2011) have investigated causality between regional house prices. The latter strand of literature is closely related to the literature on the so-called *ripple effect hypothesis*, whereby shocks in the south east of England *ripple* across to other areas of the country. As Meen (1999) argued both strands of literature are closely related since the ripple effect hypothesis implies that "*short-term variations in regional price differentials can be very large indeed, but in the longer term some normal relative price pattern tends to be restored.*" Most studies (e.g., Giussani and Hadjimatheou, 1991; MacDonald and Taylor, 1993; Holly *et al.*, 2011) on the ripple effect hypothesis have included London house price changes as an additional regressor in the price equations for other regions and shown that the ripple effect hypothesis is a valid representation of the data. Although many studies have either assumed (e.g., Giussani and Hadjimatheou, 1991) or shown (e.g., Holly *et al.*, 2011) that London is the dominant region in the UK, other studies, such as Alexander and Barrow (1994), have shown that the south east of England might be a more appropriate base region. Despite that there has been a large interest and much statistical evidence for the ripple effect hypothesis in the UK, Meen (1999) argued that there are few studies providing convincing economic explanations. According to Meen (1999) there are four possible explanations for the ripple effect hypothesis, namely (1) migration, (2) equity transfer, (3) spatial arbitrage and (4) spatial determinant of house prices. A fifth explanation that is examined in Meen and Andrew (1998) are leads and lags in house prices. Although there have been some examples of studies investigating the ripple effect hypothesis for other countries, such as Stevenson (2004) for Ireland, Kuethe and Pede (2011) for the US and Van Dijk *et al.* (2011) for the Netherlands, most studies have examined the ripple effect hypothesis in the UK. In this paper we examine the ripple effect hypothesis for Belgium and have a particular interest for the effects on the spatial and temporal diffusion of house prices of the linguistic border in Belgium. To our knowledge, we are the first study that investigates the ripple effect hypothesis in a multilingual country, such as Belgium. Although Goffette-Nagot *et al.* (2011) and De Bruyne and Van Hove (2013) explored the effects of the linguistic border on the spatial pattern of house prices (Goffette-Nagot *et al.*, 2011) and land prices (De Bruyne and Van Hove, 2013) using a single cross-section of data, we are the first study examining whether house prices are converging in the long-run and whether some pattern of spatial causality exists, that is, whether regional house prices are driven by house prices in a single dominant region.

3 Methodology

3.1 Long-run equilibria

Abbott and De Vita (2013) classify tests of regional house price convergence within a cointegration framework in two main approaches. The first approach applies system cointegration techniques directly to the series and tests for existence of $N-1$ cointegrating vectors among the N series. But, as Holly *et al.* (2011) argue, cointegration is a necessary, but not sufficient, condition for the long-run convergence of regional house prices. Convergence requires regional house prices to be cotrended with the cointegrating vector of the form $(1,-1)$ in addition to being cointegrated.[4] The second approach tests for unit roots (or stationarity) in $N-1$ regional house price differentials with respect to a base region or in the ratio of house prices in a given region relative to the national figure as the numeraire. Although a cointegrating vector of the form $(1,-1)$ is implicitly assumed here, choosing a benchmark is required. The results are consequently dependent upon the choice of the benchmark, which can be misleading.

Pesaran (2007) proposes a pair-wise approach to test for output convergence that considers all $N(N-1)/2$ possible pairs of log per-capita output gaps across N economies. The approach allows for unit root tests to be conducted on all $N(N-1)/2$ possible pairs and a general probabilistic definition of output convergence is proposed, which suggests that all output gaps must be stationary with a constant mean (Pesaran, 2007). Holmes *et al.* (2011) examine long-run house price convergence among US states and find evidence in favor of convergence. Abbott and De Vita (2013) apply this pair-wise approach to test for stochastic convergence in UK regional house prices and find that there is no evidence of long-run convergence among regional house prices. In the current study we also perform unit root tests on all $N(N-1)/2$ pairs of regional house price differentials, which corresponds to the assumption of co-trending behavior of p_{it} and p_{jt} in the long-run. We thereby contribute to the literature that has emerged on regional convergence of house prices using the recently developed pair-wise approach. The full pair-wise approach furthermore allows us to look at possible clustering of cointegration outcomes, with an emphasis on possible linguistic patterns in convergence behavior.

3.2 Spatial weight matrices

Throughout the empirical analysis we use different spatial weights matrices to ascertain the robustness of our results. Spatial weights matrices, which are the mathematical representation of the spatial structure in the data, are a necessary element in most regression models which take into

[4] This implies that the series $p_{it}-p_{jt}$ are stationary $\forall i,j \in N$

account spatial aspects and have been subject of debate. Getis and Aldstadt (2004) mention 11 well-known and frequently used schemes for constructing the spatial weights matrix W.[5] In the current study we use 2 different schemes to ensure the robustness of the results.

3.2.1 Contiguity

The first scheme we employ in the current study is the so-called contiguity criterion. Regions i and j are considered to be *neighbors* when they share a common border.

$$W_{ij}^{con} = \begin{cases} 1 \text{ if } i \text{ and } j \text{ are neighbors} \\ 0 \text{ otherwise} \end{cases} \tag{1}$$

Since we want to take into account the effects of the linguistic border, we have to take into account the linguistic area in which regions i and j are located. We split the previous spatial weights matrix W^{con} into 2 separate spatial weights matrices. W_o^{con} is the spatial weights matrix that contains the weights for regions that are both neighbors and lie within the same linguistic region. W_c^{con} contains the weights for regions that are neighbors and lie on opposite sides of the linguistic border.

$$\begin{aligned} W_{ijo}^{con} &= \begin{cases} 1 \text{ if } i \text{ and } j \text{ are neighbors and on the } \textit{same} \text{ side of the linguistic border} \\ 0 \text{ otherwise} \end{cases} \\ W_{ijc}^{con} &= \begin{cases} 1 \text{ if } i \text{ and } j \text{ are neighbors and on } \textit{opposite} \text{ sides of the linguistic border} \\ 0 \text{ otherwise} \end{cases} \end{aligned} \tag{2}$$

3.2.2 Inverse distance

A different scheme that has frequently appeared in the spatial econometrics literature is the inverse distance scheme. The inverse distance scheme, which relates to Tobler's first law of geography[6], is easily applied by calculating the inverse of the distance between all pairs of regions i and j.[7] Element (i,j) of W^{id} can thus simply be calculated as:

$$W_{ij}^{id} = 1/d_{ij}, \text{ where } d_{ij} \text{ denotes the geographical distance between regions } i \text{ and } j \tag{3}$$

We can also again take into account the effects of the linguistic border by calculating two separate spatial weights matrices W_o^{id} and W_c^{id}.

[5] Spatially contiguous neighbors, inverse distances raised to some power, lengths of shared borders divided by the perimeter, bandwidth as the nth nearest neighbor distance, ranked distances, constrained weights for an observation equal to some constant, all centroids within distance d, n nearest neighbors, bandwidth distance decay, Gaussian distance decline and "Tri-cube" distance decline function (Getis and Aldstadt, 2004)

[6] *Everything is related to everything else, but near things are more related than distant things* (Tobler, 1970).

[7] In the current study we calculated the inverse of the distance between the different capital cities of the respective provinces in our sample.

$$W_o^{id} = W_o^{con} \circ W^{id} \text{ and } W_c^{id} = W_c^{con} \circ W^{id} \tag{4}$$

where $\circ$ denotes the Hadamard product (element-by-element) of matrices.

The spatial weights matrices are then row-normalized ($\Sigma_{j=1}^{N} s_{ij} = 1,\ i = 1,..,N$) as has been conventional in the spatial econometrics literature (Anselin, 1988).

3.3 Empirical model

We draw upon the work by Holly *et al.* (2011) who proposed a spatio-temporal model for house prices. As in Holly *et al.* (2011) we are interested in the propagation of (log) prices, p_{it}, over time, indexed by $t = 1, 2, .., T$, and space, where space is represented by the different regions and indexed by $i = 0, 1, 2, .., N$. We furthermore want to allow for the possibility of a dominant region, region 0, and error correcting mechanisms. Shocks to the dominant region, region 0, are propagated to other regions immediately, whilst shocks to other regions have little immediate impact on region 0. The error correction mechanism take into account possible long-run equilibrium relationships between the different regions and are allowed for when the co-trending vector is found to be a valid representation of the data. For the dominant region, region 0, the following price equation thus applies:

$$\begin{aligned} \Delta p_{0t} = {} & \phi_{0s_o}(p_{0,t-1} - \bar{p}_{0,t-1}^{s_o}) + \phi_{0s_c}(p_{0,t-1} - \bar{p}_{0,t-1}^{s_c}) + \alpha_0 + \beta_{01}\Delta p_{0,t-1} + \gamma_{01}\Delta \bar{p}_{0,t-1}^{s_o} \\ & + \delta_{01}\Delta \bar{p}_{0,t-1}^{s_c} + \epsilon_{0t} \end{aligned} \tag{5}$$

and for the remaining regions the price equations are given by:

$$\begin{aligned} \Delta p_{it} = {} & \phi_{i0}(p_{i,t-1} - p_{0,t-1}) + \phi_{is_o}(p_{i,t-1} - \bar{p}_{i,t-1}^{s_o}) + \phi_{is_c}(p_{i,t-1} - \bar{p}_{i,t-1}^{s_c}) + \alpha_i \\ & + \beta_{i1}\Delta p_{i,t-1} + \gamma_{i1}\Delta \bar{p}_{i,t-1}^{s_o} + \delta_{i1}\Delta \bar{p}_{i,t-1}^{s_c} + \kappa \Delta p_{0t} + \epsilon_{it} \end{aligned} \tag{6}$$

The spatially lagged variables in the different price equations are created using the spatial weights matrices described in the previous subsection. The model allows for error correction mechanisms with respect to the dominant region, neighboring regions in the same linguistic region and neighboring regions across the linguistic border. In the empirical application we allow for higher order lags.[8]

[8] The model presented here is a first-order linear model with error correction component, which intends to illustrate the main features that are present in the model.

3.4 Choice of the dominant region

In the empirical model described in the previous subsection we allow for a dominant region, where shocks to this dominant region are contemporaneously and spatially propagated to the remaining regions without immediate feedback effects. Consequently, this implies that we have to check whether a region is a valid candidate. The UK literature has frequently either assumed (e.g., Giussani and Hadjimatheou, 1991) or shown (e.g., Holly *et al.*, 2011) that London is the dominant region, although Alexander and Barrow (1994) found that the south east of England is a more likely candidate. In the current study we follow Holly *et al.* (2011) and first estimate bivariate VAR(4) models with error correcting coefficients. This allows us to assess whether prices in certain regions are long-run forcing, in the sense of Granger and Lin (1995), upon prices in other regions. We thus estimate the error correction coefficients and their associated t-ratios in a bivariate VAR(4) model for each price pair of regions i and j using a SUR algorithm[9].

$$\left.\begin{aligned} \Delta p_{it} &= \phi_{ij}(p_{i,t-1} - p_{j,t-1}) + \Sigma_{l=1}^{4} a_{ijl}\Delta p_{i,t-l} + \Sigma_{l=1}^{4} b_{ijl}\Delta p_{j,t-l} + \epsilon_{ijt} \\ \Delta p_{jt} &= \phi_{ji}(p_{j,t-1} - p_{i,t-1}) + \Sigma_{l=1}^{4} a_{jil}\Delta p_{j,t-l} + \Sigma_{l=1}^{4} b_{jil}\Delta p_{i,t-l} + \epsilon_{jit} \end{aligned}\right\} \forall i, j \tag{7}$$

where $i \neq j$ and $i = 0, 1, .., N$ and $j = 0, 1, .., N$.

3.5 Exogeneity tests

From the empirical specifications for the remaining regions the attentive reader notices that the price change in the dominant region, Δp_{0t} is included as a contemporaneous effect for every region i, while Δp_{it} is not included as a contemporaneous effect in the price equation for the dominant region. This specification implicitly assumes that the shocks ϵ_{it} are independently distributed across i and $\Delta \bar{p}_{0t}$ is weakly exogenous in the price equations for regions $i = 1, 2, .., N$. This assumption can be tested using the procedure proposed by Wu (1973).[10]

Denote the OLS residuals for the dominant region by:

$$\begin{aligned} \hat{\epsilon}_{0t} =& \Delta p_{0t} - \hat{\phi}_{0s_o}(p_{0,t-1} - \bar{p}^{s_o}_{0,t-1}) - \hat{\phi}_{0s_c}(p_{0,t-1} - \bar{p}^{s_c}_{0,t-1}) - \hat{\alpha}_0 - \hat{\beta}_{01}\Delta p_{0,t-1} \\ & - \hat{\gamma}_{01}\Delta \bar{p}^{s_o}_{0,t-1} - \hat{\delta}_{01}\Delta \bar{p}^{s_c}_{0,t-1}, \end{aligned} \tag{8}$$

and run the auxiliary regressions:

[9] Seemingly Unrelated Regressions (Zellner, 1963)

[10] The test proposed by Wu (1973) is asymptotically equivalent to the procedure proposed by Hausman (1978). In the regression tables we therefore refer to the Wu-Hausman test statistics.

$$\Delta p_{it} = \phi_{i0}(p_{i,t-1} - p_{0,t-1}) + \phi_{is_o}(p_{i,t-1} - \bar{p}^{s_o}_{i,t-1}) + \phi_{is_c}(p_{i,t-1} - \bar{p}^{s_c}_{i,t-1}) + \alpha_i + \beta_{i1}\Delta p_{i,t-1} + \gamma_{i1}\Delta\bar{p}^{s_o}_{i,t-1} + \delta_{i1}\Delta\bar{p}^{s_c}_{i,t-1} + \kappa\Delta p_{ot} + \lambda_i\hat{\epsilon}_{0t} + \epsilon_{it} \tag{9}$$

for $i = 1, 2, .., N$ and use a standard t-test to test the hypothesis that $\lambda_i = 0$ in every regression.

3.6 Generalized spatio-temporal impulse response functions

Although the price equations have been decoupled for estimation purposes, we need to solve the full system of equations to obtain the spatio-temporal impulse response functions. These can then be used to simulate the short- and long-run effects of shocks to one or multiple regions and help us interpret the results found earlier.

$$\Delta p_t = \alpha + \phi p_{t-1} + (\beta_1 + \gamma_1 + \delta_1)\Delta p_{t-1} + \kappa_0 \Delta p_t + \epsilon_t \tag{10}$$

where $p_t = (p_{0t}, p_{1t}, .., p_{Nt})$, $\alpha = (\alpha_0, \alpha_1, .., \alpha_N)$, $\epsilon_t = (\epsilon_{0t}, \epsilon_{1t}, .., \epsilon_{Nt})$,

$$\phi = \begin{pmatrix} \phi_{0s_o} + \phi_{0s_c} & 0 & . & . & 0 \\ -\phi_{10} & \phi_{1s_o} + \phi_{1s_c} + \phi_{10} & . & . & 0 \\ . & . & . & . & . \\ . & . & . & . & . \\ -\phi_{N-1,0} & 0 & . & . & 0 \\ -\phi_{N0} & 0 & . & . & \phi_{Ns_o} + \phi_{Ns_c} + \phi_{N0} \end{pmatrix} - \begin{pmatrix} \phi_{0s_o} s'_{0,o} \\ \phi_{1s_o} s'_{1,o} \\ . \\ . \\ \phi_{N-1,s_o} s'_{N-1,o} \\ \phi_{Ns_o} s'_{N,o} \end{pmatrix}$$

$$- \begin{pmatrix} \phi_{0s_c} s'_{0,c} \\ \phi_{1s_c} s'_{1,c} \\ . \\ . \\ \phi_{N-1,s_c} s'_{N-1,c} \\ \phi_{Ns_c} s'_{N,c} \end{pmatrix}, \ \beta_1 = \begin{pmatrix} \beta_{01} & 0 & . & . & 0 & 0 \\ 0 & \beta_{11} & . & . & 0 & 0 \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ 0 & 0 & . & . & \beta_{N-1,1} & 0 \\ 0 & 0 & . & . & 0 & \beta_{N1} \end{pmatrix}, \ \gamma_1 = \begin{pmatrix} \gamma_{01} s'_{0,o} \\ \gamma_{11} s'_{1,o} \\ . \\ . \\ \gamma_{N-1,1} s'_{N-1,o} \\ \gamma_{N1} s'_{N,o} \end{pmatrix},$$

$$\delta_1 = \begin{pmatrix} \delta_{01} s'_{0,c} \\ \delta_{11} s'_{1,c} \\ . \\ . \\ \delta_{N-1,1} s'_{N-1,c} \\ \delta_{N1} s'_{N,c} \end{pmatrix} \text{ and } \kappa_0 = \begin{pmatrix} 0 & 0 & . & . & 0 & 0 \\ \kappa_{10} & 0 & . & . & 0 & 0 \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ \kappa_{N-1,0} & 0 & . & . & 0 & 0 \\ \kappa_{N0} & 0 & . & . & 0 & 0 \end{pmatrix}$$

where $s'_{i,o} = (s_{i0,o}, s_{i1,o}, .., s_{iN,o})$ and $s'_{i,c} = (s_{i0,c}, s_{i1,c}, .., s_{iN,c})$ denote the vectors containing the spatial weights of neighboring provinces in the same, indicated by subscript o, or opposite, denoted by subscript c, linguistic region.

Since Δp_t is on both sides of the equality sign, we need to solve the model for price changes first:

$$\Delta p_t = \mu + \Pi p_{t-1} + \Lambda_1 \Delta p_{t-1} + \Omega \epsilon_t, \tag{11}$$

where $\Omega = (I_{N+1} - \kappa_0)^{-1}$, $\Pi = \Omega H$ and $\Lambda = \Omega(\beta_1 + \gamma_1 + \delta_1)$. Equation (11), however, still contains both price changes and prices, but one can easily rewrite the model so that it only contains prices.

$$p_t = \mu + \Phi_1 p_{t-1} + \Phi_2 p_{t-2} + \Omega \epsilon_t, \tag{12}$$

where $\Phi_1 = I_{N+1} + \Lambda_1$ and $\Phi_2 = -\Lambda_1$. Note that equation (12) can be interpreted as a simple VAR model in prices, where all the spatial and temporal dependencies are captured in the coefficient matrices Φ_1, Φ_2 and Ω.

Given that the Wu (1973) test of weak exogeneity of p_{0t} is not rejected, it would be reasonable to assume that $\Sigma(\epsilon_0, \epsilon_i) = 0$, for $i = 1, 2, .., N$ and the impulse responses of a unit (one standard error) shock to house prices in the dominant region on the other regions at horizon h periods ahead will be given by:

$$\begin{aligned} g_0(h) &= E(p_{t+1} | \epsilon_{0t} = \sqrt{\sigma_{00}}, \mathcal{I}_{t-1}) \\ &= \sqrt{\sigma_{00}} \Psi_h \Omega e_0, \text{ for } h = 0, 1, .., \end{aligned} \tag{13}$$

where $\mathcal{I}_{t-1}$ is the information set at time $t-1$, $\sigma_{00} = var(\epsilon_0)$, $e_0 = (1, 0, .., 0)$ and $\Psi_h = \Phi_1 \Psi_{h-1} + \Phi_2 \Psi_{h-2}$ for $h = 0, 1, ...,$ with initial values $\Psi_0 = I_{N+1}$ and $\Psi_h = 0$ for $h < 0$. So far, we have only analyzed the effects of shocks to a dominant region. The impulse response functions of a shock to a non-dominant region i can be derived from the work of Pesaran and Shin (1998). The generalized impulse response functions allow for the possibility of contemporaneous correlations between the different regions. The generalized impulse response function of a shock to region i are given by:

$$g_i(h) = \frac{\Psi_h \Omega \Sigma e_i}{\sqrt{\sigma_{ii}}}, \tag{14}$$

for $i = 1, 2, .., N$. e_i is a $(N+1) * 1$ vector of zeros, except for the i^{th} element, which is equal to one.

$$\Sigma = \left\{ \begin{array}{cccccc} \sigma_{00} & 0 & 0 & .. & 0 & 0 \\ 0 & \sigma_{11} & \sigma_{12} & .. & \sigma_{1,N-1} & \sigma_{1N} \\ 0 & \sigma_{21} & \sigma_{22} & .. & \sigma_{2,N-1} & \sigma_{2N} \\ .. & .. & .. & .. & .. & .. \\ 0 & \sigma_{N-1,1} & \sigma_{N-1,2} & .. & \sigma_{N-1,N-1} & \sigma_{N-1,N} \\ 0 & \sigma_{N1} & \sigma_{N2} & .. & \sigma_{N,N-1} & \sigma_{NN} \end{array} \right\}$$

where $\sigma_{ij} = E(\epsilon_i \epsilon_j)$, which can be consistently estimated from the OLS residuals, $\hat{\epsilon}_{it}$, of the individual regressions. The confidence intervals are obtained using a bootstrap procedure that is described in appendix F.

4 Data

House prices in Belgium are measured using quarterly data for all Belgian municipalities for an extensive period (1973Q1-2011Q3, $T = 155$) that are provided by ADSEI[11], the national statistics office in Belgium. The data contain the averages, median and quantiles of all transactions that occurred in a particular municipality in a particular period, and are given for different categories, that is, dwellings, apartments and villa's. Unlike studies in the UK and the US we don't have mix-adjusted, volume-weighted hedonic price indices at our disposal, but we are able to control for changes in composition and location by using fixed weights for the different municipalities and categories over time.

$$P_{it} = \Sigma_{j=1}^{K} \bar{w}_{ik} P_{ikt}, \text{ where } \bar{w}_{ik} = T^{-1} \Sigma_{t=1}^{T} w_{ikt} \tag{15}$$

where k represents the different categories (dwellings and apartments). Since the data are provided at the municipal level, we are furthermore able to exclude transactions that occurred in municipalities that are located along the borders with the Netherlands, Germany, Luxembourg and France to control for boundary effects.[12] After exclusion of the previously mentioned transactions we aggregate the data on the level of 20 *a priori* defined regions.[13] These regions largely correspond with the judicial districts in Belgium.[14] Since house prices are in nominal terms, we employ the national (not available on a more disaggregated level) Consumer Price Index (CPI), which is also provided by ADSEI, to calculate real house prices for every period ($T = 155$) in our sample. We furthermore collected data concerning real GDP (growth) from the National Bank of Belgium. These data are

[11] *Algemene Directie Statistiek en Economische Informatie* (Statistics Belgium)

[12] Appendix A displays the municipalities that have been excluded from our sample.

[13] Other aggregation procedures, such as aggregating at the level of the provinces, are possible.

[14] We only aggregated the judicial districts of Ieper and Veurne (Veurne), Mons and Tournai (Tournai), Huy and Liège (Liège), Eupen and Verviers (Verviers), Hasselt and Tongeren (Hasselt) and Arlon, Neufchâteau and Marche-en-Famenne (Arlon). 2 or more separate judicial districts were only aggregated into a single new region because of data limitations (e.g., too much municipalities along the national border).

available at a quarterly frequency from 1980Q1 up to 2011Q1 ($T = 125$). An overview of the raw data is provided in appendix B.

5 Results

5.1 Long-run equilibria

In table 2 we present the global results of the pair-wise approach that was described in the methodology section.[15] The results indicate that 46.8% (190 observations) of the regional house price differentials ($p_{it} - p_{jt}$) are stationary at the 5% level using Augmented Dickey-Fuller tests. The results also indicate that the fraction of regional house price differentials that are stationary is higher (56.3% vs 37.5%) within each linguistic area, indicating that either distance (obviously, the average distance between regions within a single linguistic area is smaller than the average distance between region i and regions across the linguistic border) or language does play a role. Furthermore, the table shows that the rate of convergence is higher among the Walloon regions than among Flemish regions.

Table 2: Fraction of regions that are cointegrated at the 5% level in a predefined subsample using log real house prices (1973Q1-2011Q3)

All	Within linguistic area			Across
	Total	Flanders	Wallonia	border
0.468 (190)	0.563 (94)	0.454 (66)	0.821 (28)	0.375 (96)

Note: The number of observations is displayed within brackets. Cointegration statistics are calculated using pairwise ADF-tests on regional house price differentials ($p_{it} - p_{jt}$), where the optimal lag is calculated using the SIC criterion.

The results confirm that regional house prices in Belgium thus display a considerable degree of coherence, despite that the evidence in the UK has been mixed. Belgium, however, is much smaller than the UK and less diverse, which might explain this coherence.

5.2 On the choice of the dominant region

Theoretically, the current model with a dominant region can be characterized as a VAR model with a dominant unit (Chudik and Pesaran, 2011). In the UK literature many authors have either assumed (e.g., Giussani and Hadjimatheou, 1991) or shown (e.g., Holly *et al.*, 2011) that London is the dominant region. The motivation for London being the most dominant region is very often that London is the largest city in Europe and a major financial center. In this paper, Antwerp (the second largest city in Belgium) turns out to be a valid candidate for the dominant region.

[15] In appendix D the full table is provided.

Although this result might seem counterintuitive, since Brussels is the largest city in and capital city of Belgium, centrally located and home to many national and international organizations, we argue that a large share of employment in Brussels is provided by governmental organizations which are less subject to market driven shocks.[16] Antwerp, however, is Belgium's largest port. A large share of the international imports and exports of Belgium go through the port of Antwerp. Moreover the port hosts one of the world's most important clusters of chemical industry. Both elements make the region of Antwerp more liable to economic conditions.[17] In table 3[18] we show that house prices in the region of Antwerp are long-run causal (Granger and Lin, 1995) upon house prices in all other regions, except for the region of Ghent.[19] We thus start from the hypothesis that the region of Antwerp is the dominant region in Belgium. In the following subsection we use Wu's (1973) test of exogeneity to validate this hypothesis.

5.3 Estimation results

In table 4 we provide the regression results for a model in which Antwerp acts as the dominant region and spatial relationships are split up into 2 separate components (within and across linguistic areas). We furthermore allow for error correction with respect to Antwerp, neighbors within the same linguistic area and neighbors across the linguistic border. All price equations are estimated using OLS and lag orders are selected using the SIC criterion using a maximum lag order of 4. The estimates for the error correction coefficients are provided in the first three columns of table 4. Although evidence in the UK literature on convergence has been mixed, our results indicate that all regions, except for Ghent, converge with respect to Antwerp, neighboring regions, or both. The 20 regions can be split up into approximately 4 separate groups. A first group that comprises Mechelen, Brussels, Leuven, Nivelles, Namur and Verviers are regions that lie along, except for Verviers, the north-south axis in Belgium and constitute the economic spine of Belgium. These regions converge directly with respect to Antwerp. Notice that Nivelles and Namur are both French-speaking areas, while Antwerp is Dutch-speaking. The initial convergence behavior thus goes across the linguistic border. A second group of regions comprises Dendermonde, Turnhout, Veurne, Oudenaarde, Charleroi, Tournai, Liège and Hasselt. These regions all convergence with respect to neighboring regions. Notice that except for Liège all regions converge only with respect to neighboring regions in the same linguistic area, which attributes a role to the linguistic border in Belgium. The third group of regions consists out of the regions Bruges, Kortrijk, Arlon and

[16] In the Brussels Capital Region approximately 38.5% of the working population is employed by the public sector, whereas in Antwerp the public sector is only responsible for 22% of total employment (source: Rijksdients voor de Sociale Zekerheid (RSZ)).

[17] The port of Antwerp provided employment for 145836 full time equivalents (FTE) in 2010, of which 60509 direct and 85327 indirect. The 10 largest employers in the port of Antwerp were: BASF, BNRC Group, Public sector, Antwerp Port Authority, General Motors Belgium, ExxonMobil Petroleum & Chemical, PSA Antwerp, M.S.C. Home terminal, Electrabel and Total Raffinaderij Belgium. The port of Antwerp was in 2010 responsible for 19.2 billion million euro's of value added, which was approximately 5.5% of the total value added of Belgium in 2010 (Mathys, 2012).

[18] The results of all pair-wise long-run causality tests are provided in table 7, which is in appendix E.

[19] Ghent, however, does not display any form of long-run causality with respect to any other region.

Table 3: Error correction coefficients in cointegrating bivariate VAR(4) of log real house prices of Antwerp and other Belgian regions (1973Q1-2011Q3)

Error correction equation for:	Antwerp (p_{0t})			other regions (p_{it})		
Regions	$\hat{\phi}_{0i}$	t-ratio	$\bar{R}^2$	$\hat{\phi}_{i0}$	t-ratio	$\bar{R}^2$
Mechelen	0.016	0.337	0.211	-0.167***	-2.923	0.304
Turnhout	0.043	1.305	0.159	-0.140***	-3.164	0.245
Brussels	-0.054	-0.933	0.273	-0.118**	-2.056	0.241
Leuven	-0.093*	-1.756	0.254	-0.231***	-3.292	0.264
Nivelles	0.042	0.767	0.230	-0.168***	-2.781	0.235
Bruges	-0.017	-0.398	0.200	-0.115**	-2.348	0.294
Kortrijk	0.003	0.090	0.189	-0.091**	-2.421	0.297
Veurne	0.008	0.268	0.165	-0.189***	-3.627	0.297
Dendermonde	0.014	0.291	0.173	-0.170***	-3.084	0.288
Ghent	-0.018	-0.588	0.182	-0.014	-0.394	0.322
Oudenaarde	0.029	0.916	0.194	-0.143***	-3.000	0.326
Charleroi	0.033	1.095	0.177	-0.052*	-1.871	0.313
Tournai	0.021	0.563	0.194	-0.095**	-2.477	0.317
Liège	0.024	0.737	0.215	-0.075**	-2.413	0.321
Verviers	0.034	0.957	0.256	-0.168***	-2.918	0.296
Hasselt	0.017	0.555	0.153	-0.103***	-2.598	0.313
Arlon	0.068*	1.902	0.197	-0.209***	-3.375	0.276
Dinant	0.03	0.860	0.151	-0.140***	-2.867	0.260
Namur	0.018	0.421	0.195	-0.090*	-1.884	0.333

Note: The table displays the results of the pair-wise long-run causality test. The coefficient ϕ_{0i}, which refers to the error correction component of Antwerp with respect to the assumed dominant region i in the equation $\Delta p_{0t} = \phi_{0i}(p_{0,t-1} - p_{i,t-1}) + \sum_{l=1}^{4} a_{0i,l}\Delta p_{0,t-l} + \sum_{l=1}^{4} b_{0i,l}\Delta p_{i,t-l} + \epsilon_{0it}$ is significant when region i is likely to be long-run causal for region 0. Intercepts are included in all the regressions. *** indicates that the error correction coefficient, ϕ_{ij}, is significant at the 1% level, ** indicates that the error correction coefficient is significant at the 5% level and * indicates that the error correction coefficient is significant at the 10% level.

Dinant. These regions converge both with respect to the dominant region and neighboring regions. Again a role can be attributed to the linguistic border. Finally, a fourth group which comprises only one region, Ghent, shows no convergence behavior. The results thus indicate that regional house prices are converging in the long run and that there is an ambiguous role for the linguistic border. Convergence initially takes place along the north-south axis in Belgium and thereby crosses the linguistic border, while in the second stage convergence occurs along the east-west dimension and displays a linguistic pattern, where regions converge with respect to neighboring regions in the same linguistic area.

The model furthermore comprises several short-run dynamics in the form of lagged own and neighboring prices. The results point out that own lagged price changes are characterized by negative coefficients, which indicates that when the growth rate was high in the previous period it will be lower today. Price changes in neighboring regions have again been split up into price changes in neighboring regions in the same linguistic area and price changes in neighboring regions that are in the other linguistic area. The results here display a strong linguistic pattern, where price changes in neighboring regions within the same linguistic area are generally positive and significant, while price changes in regions in the opposite linguistic area are insignificant in 7 out of 8 cases. The significant effects of lagged price changes in neighboring regions in the same linguistic area indicate that there is a significant role for short-term dynamics and spatial effects. The only region where shocks from neigboring regions across the linguistic border are significant is the region Nivelles which coincides with the province of Walloon Brabant. Nivelles is neighboring the regions Brussels and Leuven, which largely coincide with the province of Flemish Brabant.[20] Up until 1995 the provinces Walloon Brabant and Flemish Brabant together constituted the province of Brabant.

The contemporaneous effect of changes in house prices in Antwerp are substantial and significant in 14 out of 19 regressions, which indicates that Antwerp is a suitable dominant region. The effects furthermore seem to be related to the (economic) distance from Antwerp, with the exception of Arlon. The results from contemporaneous changes in real GDP furthermore show that Antwerp reacts more strongly on changes in real GDP than, for example, Brussels. This is intuitive as the region of Antwerp is more affected by market conditions due to a presence of the port and high share of employment in the private sector.

Finally, we report the results of the Wu-Hausman test statistics to ensure that the results are not subject to simultaneity bias. The null hypothesis states that changes in Antwerp house prices are exogenous to the evolution of house prices in other regions cannot be rejected in our setting.

5.4 Generalized spatio-temporal Impulse Response Functions

In table 4 the regression results for our price diffusion model were presented. These regression equations present a rather complicated set of interconnected relationships. A shock to the dominant region, region 0, for example is translated in a heterogeneous fashion to all other regions, which subsequently affect each other. This implies that the regression results are not easy to interpret without taking into account all system effects. Therefore, we provide Generalized spatio-temporal Impulse Response Functions which trace out the effects of shocks both over space and time, whereas convential impulse response functions only display the effect of a shock over time. The GIRF's are presented in figure 1.[21]

The GIRF's clearly provide evidence for the ripple effect hypothesis in Belgium, where a shock

[20] The region Brussels includes the Brussels Capital Region, which was not part of the province Brabant, although it was fully enclosed by the province of Brabant.

[21] In appendix 4 the Generalized spatio-temporal Impulse Response Functions are presented for each region separately together with their bootstrapped (5000 replications.) confidence intervals.

Table 4: Estimation Results of Region Specific House Price Diffusion Equation with Antwerp as the Dominant Region and Cross-Linguistic and Non-Cross-Linguistic Border Dynamics (1980Q1-2011Q1) (Part 1)

Regions	EC1 ($\hat{\phi}_{i0}$)	EC2 ($\hat{\phi}_{iso}$)	EC3 ($\hat{\phi}_{is_c}$)	Own Lag Effects ($\hat{\beta}_{i1}$)	Intra-Regional ($\hat{\gamma}_{i1}$)	Inter-Regional ($\hat{\delta}_{i1}$)	Dom. Region ($\hat{\kappa}_{i0}$)	Real GDP ($\hat{\psi}_0$)	$\hat{k}_{ia}$	$\hat{k}_{ib}$	$\hat{k}_{ic}$	Wu-Hausman Statistics	R^2
Antwerp				-0.29***	0.340***			0.924***	1	1			0.326
				(0.094)	(0.107)			(0.347)					
Mechelen	-0.19***			-0.32***	0.356***		0.317***	-0.53	1	4		-0.787	0.513
	(0.061)			(0.095)	(0.136)		(0.116)	(0.373)					
Turnhout		-0.19***		-0.25***	0.319**		0.355***	0.571	2	1		0.949	0.467
		(0.051)		(0.087)	(0.127)		(0.097)	(0.416)					
Brussels	-0.15***			-0.10	0.034	0.121	0.311***	0.467**	4	1	1	0.856	0.597
	(0.046)			(0.082)	(0.081)	(0.076)	(0.076)	(0.237)					
Leuven	-0.21***			-0.40***	0.032	0.128	0.305***	-0.04	3	4	1	0.096	0.517
	(0.072)			(0.102)	(0.172)	(0.159)	(0.106)	(0.378)					
Nivelles	-0.17***			-0.33***	0.199	0.292***	0.211***	1.07***	1	1	1	-2.095**	0.514
	(0.048)			(0.076)	(0.138)	(0.092)	(0.077)	(0.335)					
Dendermonde		-0.36***		-0.03	-0.18		0.184**	0.621	1	1		1.177	0.386
		(0.084)		(0.107)	(0.120)		(0.080)	(0.427)					
Ghent				-0.59***	0.564***		0.136	0.616	2	2		0.924	0.344
				(0.110)	(0.140)		(0.160)	(0.441)					
Namur	-0.15***			-0.43***	0.288**		0.243***	0.689*	1	1		0.602	0.481
	(0.034)			(0.090)	(0.139)		(0.092)	(0.379)					

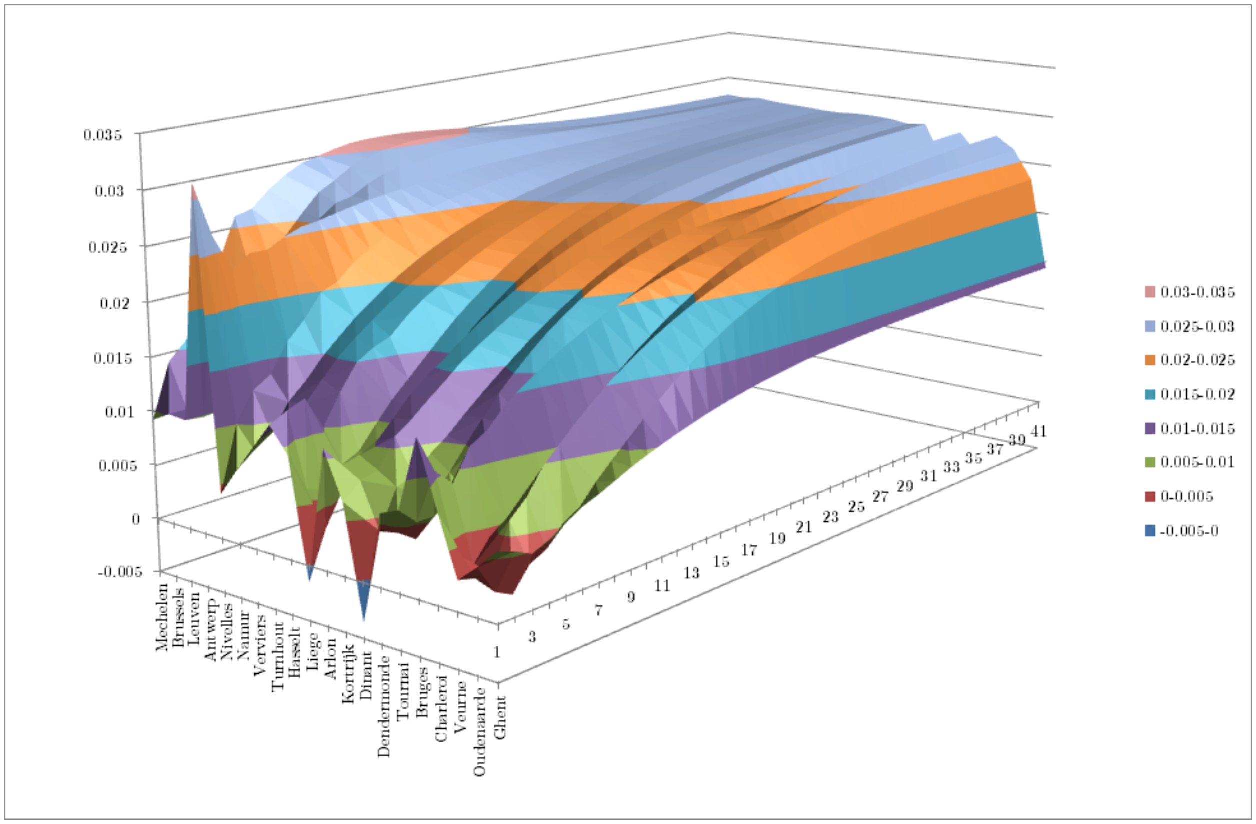
Note: The table reports estimates based on the price equations $\Delta p_{it} = \phi_{is_o}(p_{i,t-1} - p^{s_o}_{i,t-1}) + \phi_{is_c}(p_{i,t-1} - p^{s_c}_{i,t-1}) + \phi_{i0}(p_{i,t-1} - p_{0,t-1}) + \alpha_i + \sum_{l=1}^{k_{i\beta}} \beta_{il}\Delta p_{i,t-l} + \sum_{l=1}^{k_{i\gamma}} \gamma_{il}\Delta\bar{p}^{s_o}_{i,t-l} + \sum_{l=1}^{k_{i\delta}} \delta_{il}\Delta\bar{p}^{s_c}_{i,t-l} + \sum_{l=1}^{k_{i\kappa}} \kappa_{il}\Delta p_{0,t-l} + c_{i0}\Delta p_{0t} + \epsilon_{it}$,for $i = 1, 2, ..., N$. For $i = 0$, denoting the BCR equation, we have additional a priori restrictions, $\phi_{00} = c_{00} = 0$. "EC1", "EC2", "EC3", "Own lag effects", "Intra-regional", "Inter-regional" and "Dominant Region contemporaneous effects" relate to the estimates of ϕ_{i0}, ϕ_{is_o},ϕ_{is_c}, β_{i1}, γ_{i1}, δ_{i1} and κ_{i0}. Standard errors are shown in parenthesis. *** signifies that the test rejects the null at 1% level, ** at the 5% level, and * at the 10% level. Wu-Hausman is the t-ratio for testing $H_0 : {}_i = 0$ in the augmented regression $\Delta p_{it} = \phi_{is_o}(p_{i,t-1} - p^{s_o}_{i,t-1}) + \phi_{is_c}(p_{i,t-1} - p^{s_c}_{i,t-1}) + \phi_{i0}(p_{i,t-1} - p_{0,t-1}) + \alpha_i + \sum_{l=1}^{k_{i\beta}} \beta_{il}\Delta p_{i,t-l} + \sum_{l=1}^{k_{i\gamma}} \gamma_{il}\Delta\bar{p}^{s_o}_{i,t-l} + \sum_{l=1}^{k_{i\delta}} \delta_{il}\Delta\bar{p}^{s_c}_{i,t-l} + \sum_{l=1}^{k_{i\kappa}} \kappa_{il}\Delta p_{0,t-l} + c_{i0}\Delta p_{0t} + \lambda_i\hat{\epsilon}_{0t} + \epsilon_{it}$, where ϵ_{0t} is the residual of the Antwerp price equation. In selecting the lag orders, $k_{i\beta}$, $k_{i\gamma}$ and $k_{i\kappa}$ the maximum lag-order is set to 4. All the regressions include an intercept term, 3 seasonal dummies and an additional dummy-variable to account for the change in the classification process of ADSEI in 2005.

Table 4: Estimation Results of Region Specific House Price Diffusion Equation with Antwerp as the Dominant Region and Cross-Linguistic and Non-Cross-Linguistic Border Dynamics (1980Q1-2011Q1) (Part 2)

Regions	EC1 ($\hat{\phi}_{i0}$)	EC2 ($\hat{\phi}_{iso}$)	EC3 ($\hat{\phi}_{is_c}$)	Own Lag Effects ($\hat{\beta}_{i1}$)	Intra-Regional ($\hat{\gamma}_{i1}$)	Inter-Regional ($\hat{\delta}_{i1}$)	Dom. Region ($\hat{\kappa}_{i0}$)	Real GDP ($\hat{\psi}_0$)	$\hat{k}_{ia}$	$\hat{k}_{ib}$	$\hat{k}_{ic}$	Wu-Hausman Statistics	R^2
Bruges	-0.17***	-0.20**		-0.20**	-0.02		0.422***	1.05***	1	1		0.924	0.521
	(0.048)	(0.085)		(0.092)	(0.104)		(0.095)	(0.386)					
Kortrijk	-0.14***		-0.18*	-0.13	-0.07	-0.06	0.206**	0.565	1	1	1	1.861*	0.344
	(0.032)		(0.099)	(0.114)	(0.115)	(0.107)	(0.098)	(0.383)					
Veurne		-0.71***		-0.03	-0.37**		0.007	0.427	1	1		0.982	0.386
		(0.137)		(0.096)	(0.178)		(0.142)	(0.502)					
Oudenaarde		-0.39***		-0.28***	-0.10	-0.05	0.084	-0.16	1	1	1	0.103	0.398
		(0.084)		(0.091)	(0.222)	(0.142)	(0.148)	(0.541)					
Charleroi		-0.34***		-0.15	-0.19		0.188***	0.307	1	1		0.949	0.544
		(0.054)		(0.094)	(0.121)		(0.069)	(0.269)					
Tournai		-0.23**		-0.37***	0.302*	0.001	0.252***	0.168	2	4	1	-1.256	0.595
		(0.095)		(0.121)	(0.162)	(0.107)	(0.085)	(0.370)					
Liège		-0.12*	-0.20***	-0.25**	0.087	-0.01	-0.04	0.621*	1	1	1	-0.435	0.575
		(0.076)	(0.060)	(0.104)	(0.109)	(0.080)	(0.079)	(0.326)					
Verviers	-0.17***			-0.36***	0.214*		0.314**	0.449	2	1		-0.451	0.472
	(0.046)			(0.093)	(0.119)		(0.130)	(0.571)					
Hasselt		-0.32***		-0.32***	-0.10	-0.04	0.301***	0.259	1	1	1	0.165	0.441
		(0.088)		(0.118)	(0.108)	(0.097)	(0.105)	(0.603)					
Arlon	-0.20***	-0.29**		-0.15	0.124		0.327***	0.943	2	1		-0.316	0.425
	(0.058)	(0.132)		(0.128)	(0.178)		(0.126)	(0.705)					
Dinant	-0.11**	-0.33**		-0.23**	0.298		0.010	1.02**	1	1		-0.565	0.425
	(0.052)	(0.137)		(0.104)	(0.186)		(0.122)	(0.472)					

Note: Standard errors are shown in parenthesis. *** signifies that the test rejects the null at 1% level, ** at the 5% level, and * at the 10% level. In selecting the lag orders, $k_{i\beta}$, $k_{i\gamma}$ and $k_{i\kappa}$ the maximum lag-order is set to 4. All the regressions include an intercept term, 3 seasonal dummies and an additional dummy-variable to account for the change in the classification process of ADSEI in 2005.

Figure 1: Generalized spatio-temporal Impulse Response Functions (horizon = 40)



Note: the regions are ordered according to the level of the GIRF at horizon = 20.

to the dominant region slowly propagates to other regions. The GIRF's furthermore clearly show that the regions along the north-south axis converge faster with respect to the dominant region than regions that are geographically and economically less proximate. Thereafter regions that are geographically proximate converge due to regional spill-overs. Note that although it cannot be seen from this graph this occurs *within* each linguistic area, which attributes a certain role to the linguistic border.

6 Conclusion

In this paper we are particularly interested in the effects of the linguistic border in Belgium on the spatial and temporal diffusion of house prices. The ripple effect hypothesis has so far mainly been studied in the UK. Here, we present the first results confirming the ripple effect hypothesis for Belgium. We use regional house price data at the level of the judicial districts (N=20) at a quarterly frequency (1973Q1-2011Q3, T=155) to investigate our research question. In a first step we used the recently developed pair-wise approach (Pesaran, 2007) to assess whether regional house prices are converging in the long-run and found that there is a high degree of coherence among regional house prices in Belgium. The results of this approach furthermore showed that the degree of coherence among regional house prices is higher for regions that are part of the same linguistic area, which implies that the linguistic border might indeed act as a barrier.

In a second step we used the concept of long-run causality (Granger and Lin, 1995) and estimated a bivariate VAR(4) model with error correction coefficients. We found that Antwerp is more likely to be the dominant region than, for example, Brussels, which is the largest city in Belgium and the capital city of Belgium (and Europe). We argue that Antwerp is a more likely candidate since it is more prone to international economic conditions due to the presence of the port, its role in international trade and the presence of a large cluster of chemical industry. Moreover, in Brussels, a high share of people is employed by the public sector, which is less subject to economic shocks. After assessing the degree of coherence among regional house prices and our first strategy to determine the dominant region we estimated a similar model as in Holly et al. (2011) and found that regional house prices in Belgium indeed display a high degree of convergence.

Although convergence initially occurs along the centrally located north-south axis, which constitutes the economic spine of Belgium and includes both Flemish and Walloon regions, thereafter it mainly occurs within each linguistic area. The results furthermore show that almost all spillover effects with respect to neighboring regions across the linguistic border are insignificant, while a substantial share of the spillover effects with respect to neighboring regions within the same linguistic area are significant. This suggests that despite that initially economic factors play a role, linguistic differences are important. The Generalized spatio-temporal Impulse Response Functions finally confirm the so-called ripple effect hypothesis for Belgium, where shocks to a dominant region, Antwerp, slowly propagate over space and time to other regions.

Although we use regional house price transaction data and data concerning real GDP to control for economic conditions, future research should try to take into account wage differentials between the different regions. Regional data concerning wages and/or GDP, however, are unfortunately not available at this given moment at the level of the judicial districts, which implies that we have to restrict the current analysis.

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Appendices

A Belgian regions and border municipalities

Figure 2: Regions, provinces, coastal municipalities and border municipalities

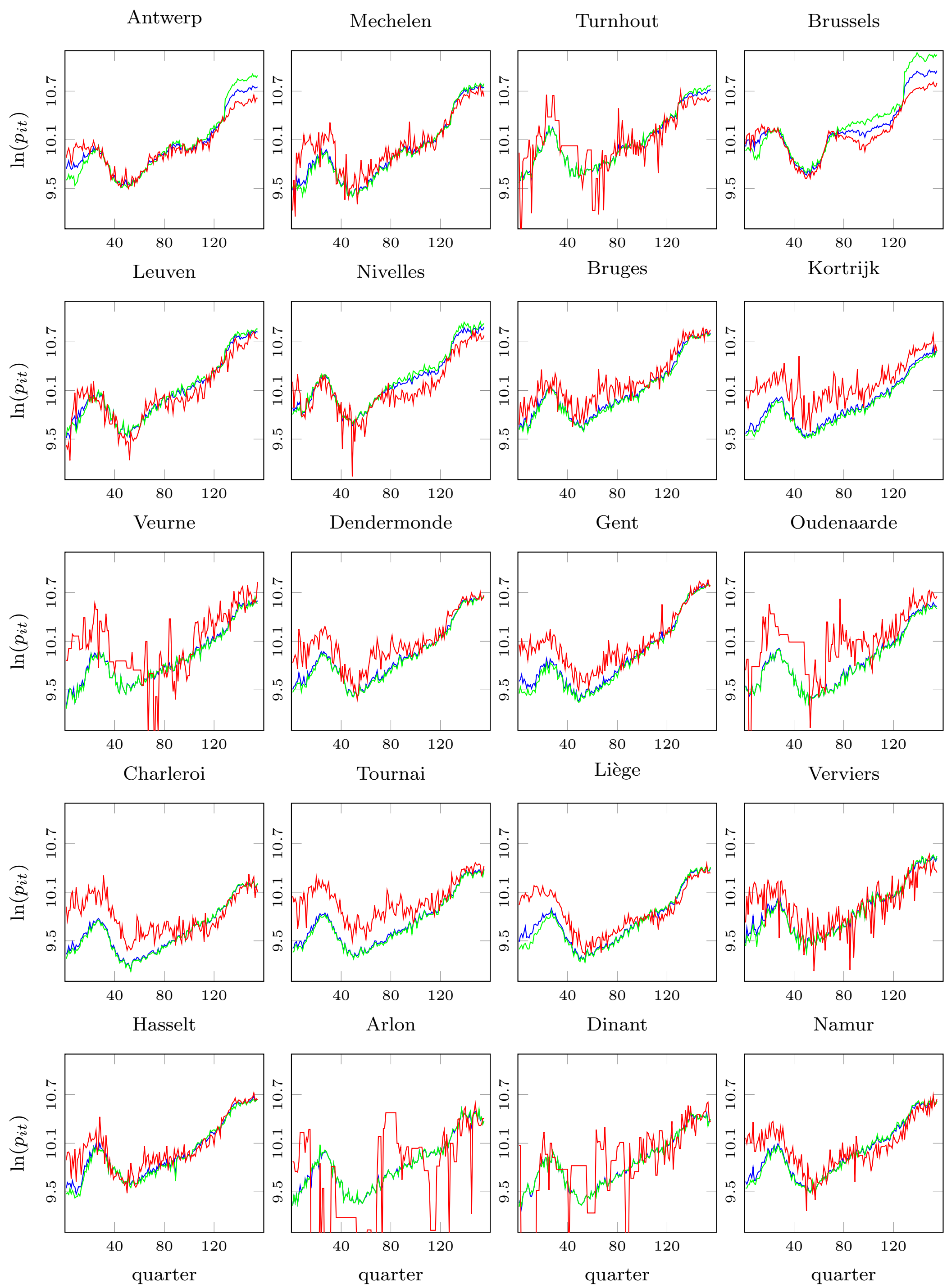
B Overview of the data

The series are presented in figure 3.

C ADF Tests of the individual series

The results are presented in table 5.

Figure 3: Log real house prices 1973Q1-2011Q3 for the different regions (mix-adjusted series: blue, dwellings: green, apartments: red)



D Long-run equilibria

The results of the Augmented Dickey Fuller tests on regional house price differentials $p_{it} - p_{jt}$ can be found in table 6.

Table 5: Augmented Dickey-Fuller (ADF) test statistics (1973Q1-2011Q3)

	Mix-adjusted		Dwellings		Apartments	
Regions	ln(.)	Δln(.)	ln(.)	Δln(.)	ln(.)	Δln(.)
Antwerp	-.96	-9.50***	-.857	-7.72***	-1.34	-13.0***
Arlon	-1.38	-11.6***	-1.32	-11.4***	-4.09***	-3.17**
Bruges	-.895	-10.2***	-.824	-9.20***	-1.71	-17.3***
Brussels	-1.72	-2.78*	-1.25	-7.09***	-1.40	-2.84*
Charleroi	-1.51	-3.83***	-1.46	-3.93***	-1.24	-14.0***
Dendermonde	-.965	-11.1***	-.918	-10.8***	-1.66	-13.3***
Dinant	-1.33	-11.0***	-1.25	-11.2***	-3.58**	-3.30**
Ghent	-1.1	-12.0***	-1.11	-12.0***	-1.00	-11.4***
Hasselt	-.979	-10.0***	-1.07	-10.3***	-1.67	-8.55***
Kortrijk	-.842	-10.9***	-.69	-11.0***	-1.85	-11.9***
Leuven	-1.1	-11.6***	-1.12	-10.6***	-1.32	-5.58***
Li‘ege	-1.18	-3.26**	-1.16	-2.75*	-.713	-11.5***
Mechelen	-1.38	-4.80***	-1.07	-9.74***	-1.48	-10.5***
Namur	-.922	-3.30**	-1.07	-3.16**	-1.25	-14.6***
Nivelles	-1.08	-8.61***	-1.05	-4.08***	-2.33	-13.0***
Oudenaarde	-1.04	-10.6***	-1.05	-11.5***	-3.12*	-4.98***
Tournai	-1.23	-2.84*	-1.21	-2.91**	-1.73	-14.2***
Turnhout	-1.16	-10.9***	-1.06	-4.59***	-2.45	-6.63***
Verviers	-.991	-12.6***	-1.04	-12.5***	-2.01	-11.5***
Veurne	-1.37	-12.0***	-1.45	-11.7***	-1.63	-4.86***

Note: the lag orders are selected using the SIC-criterion. A trend is added for the series in levels. *** signifies that the test rejects the null at 1% level, ** at the 5% level, and * at the 10% level.

E Long-run causality

The results of the bivariate VAR(4) model can be found in table 7.

F Bootstrap GIRF confidence intervals

We computed the bootstrapped confidence intervals for the estimates $g_i(h)$, over h and i, to evaluate their statistical significance. We use the residuals of the estimated model and obtain B bootstrap samples based on the DGP:

$$p_t^{(b)} = \hat{\mu} + \sum_{l=1}^{k+1} \hat{\Phi}_l p_{t-1}^{(b)} + \hat{\Omega}\hat{\epsilon}_t^{(b)}, \tag{16}$$

where $\hat{\epsilon}_t^{(b)} = \hat{\sum}^{1/2} \upsilon_t^{*(b)}$, where the elements of $\upsilon_t^{*(b)}$ are random draws with replacement from the

Table 6: Long-run equilibria

Regions	ANT	MEC	TUR	BRX	LEU	NIV	BRU	KOR	VEU	DEN	GHE	OUD	CHA	TOU	LIE	VER	HAS	ARL	DIN	NAM
ANT	n/a	**	*	**	***	***	**		***	***						**			*	*
MEC	**	n/a		*	***					**	*									
TUR	*		n/a	*		***		***	***			***	*	***	**	**	***	***	***	**
BRX	**	*	*	n/a	**	**	*		**	*								*	*	
LEU	***	***		**	n/a	***	***		*	***	***	***			*		***			
NIV	***		***	**	***	n/a	***	*	***	***		***		*		***	**	**	***	***
BRU	**			*	***	***	n/a		***	***		***					***		**	
KOR			***			*		n/a	***	*			*		*	***	***	***	***	*
VEU	***		***	**	*	***	***	***	n/a	***					**	*	***	***	***	***
DEN	***	**		*	***	***	***	*	***	n/a		***				**	***	**	*	
GHE		*			***						n/a									
OUD			***		***	***	***			***		n/a		**	***	***	***	***	***	***
CHA			*					*					n/a	**	***	***		***	***	
TOU			***			*						**	**	n/a	**	***	*	***	***	**
LIE			**		*			*	**			***	***	**	n/a	**	*	***	***	*
VER	**		**			***		***	*	**		***	***	***	**	n/a	***	***	***	***
HAS			***		***	**	***	***	***	***		***		*	*	***	n/a	***	***	**
ARL			***	*		**		***	***	**		***	***	***	***	***	***	n/a	***	***
DIN	*		***	*		***	**	***	***	*		***	***	***	***	***	***	***	n/a	***
NAM	*		**			***		*	***			***		**	*	***	**	***	***	n/a

Note: the *, ** and *** indicate that the regional house price differential $p_{it} - p_{jt}$ is stationary at the 10%, 5% and 1% level using a simple ADF-test, where the optimal lag is selected using the SIC criterion.

Table 7: Long-run causality

	ASSUMED DOMINANT REGION (region i)																			
Region j	ANT	MEC	TUR	BRX	LEU	NIV	BRU	KOR	VEU	DEN	GHE	OUD	CHA	TOU	LIE	VER	HAS	ARL	DIN	NAM
ANT	n/a				*													*		
MEC	***	n/a		**	***						**									
TUR	***		n/a	***	***	**	***	***	**	**	**	**	**	***	**	***	*	**	**	***
BRX	**			n/a																
LEU	***			***	n/a													*	*	
NIV	***			*	***	n/a	**													*
BRU	**	*		**	***		n/a													
KOR	**	*		**	***	**	*	n/a												**
VEU	***	***	***	***	***	***	***	**	n/a	**	**	*		**	*	**	**	**	**	***
DEN	***	***		**	***	**	**			n/a	**									
GHE											n/a				*					
OUD	***	**		***	***	**	**	*		**	**	n/a		**	**	**		**		***
CHA	*			*	**			**					n/a	**		**		**		**
TOU	**			**	***									n/a		*				**
LIE	**	**	*	**	***	**	**	*		**				*	n/a	*		**	*	***
VER	***	**		***	***	**	*	*		*				*		n/a				***
HAS	***	*	**	***	***	**	***	**	**	***	*	*	*	**	**	**	n/a	**	**	***
ARL	***		*	***	**	***	*	***		**			***	***	***	***		n/a	***	***
DIN	***		***	***	**	***	**	***		*			**	***	**	***		***	n/a	***
NAM	*			*	***															n/a

Note: the *, ** and *** indicate that the assumed region, region i, is long-run forcing upon region j at the respectively 10%, 5% or 1% level.

transformed residual matrix, $\hat{\sum}^{-1/2}(\hat{\epsilon}_1, \hat{\epsilon}_2, ..., \hat{\epsilon}_T)$. The $k+1$ initial observations are equated to the original data.

Next, we can reestimate the model, equations (5) and (6), for all B bootstrap samples and construct the corresponding GIRF's:

$$\hat{g}_i^{(b)}(h) = \frac{\hat{\Psi}_h^{(b)} \hat{\Omega}^{(b)} \hat{\Sigma}^{(b)} e_i}{\sqrt{\hat{\sigma}_{ii}^{(b)}}} \tag{17}$$

for $h = 0, 1, ..., H$ and $i = 0, 1, ..., N$. It then follows that the $100(1-\alpha)\%$ confidence interval is obtained as $\alpha/2$ and $1-\alpha/2$ quantiles of $\hat{g}_i^{(b)}(h)$ for each h and i. Note that the bootstrap samples are generated using the price equations selected at the estimation stage.

G Results baseline model

The results are presented in table 8.

H Robustness check: inverse distance weights matrix

The results are presented in table 9.

Table 8: Estimation Results of Region Specific House Price Diffusion Equation with Antwerp as the Dominant Region (1973Q1-2011Q3) (Part 1)

			Lag-orders $\{\hat{k}_{i\beta},\hat{k}_{i\gamma}\}$ selected by BIC							
Regions	EC1 ($\hat{\phi}_{i0}$)	EC2 ($\hat{\phi}_{is}$)	Own Lag Effects ($\hat{\beta}_{i1}$)	Neighbor Lag Effects ($\hat{\gamma}_{i1}$)	Dom. Region ($\hat{\kappa}_{i0}$)	($\hat{\psi}_{i0}$)	$\hat{k}_{ia}$	$\hat{k}_{ib}$	Wu-Hausman Statistics	R^2
Antwerp			-0.29***	0.340***		0.924***	1	1		0.326
			(0.094)	(0.107)		(0.347)				
Mechelen	-0.19***		-0.32***	0.356***	0.317***	-0.53	1	4	-0.787	0.513
	(0.061)		(0.095)	(0.136)	(0.116)	(0.373)				
Turnhout		-0.19***	-0.25***	0.319**	0.355***	0.571	2	1	0.949	0.467
		(0.051)	(0.087)	(0.127)	(0.097)	(0.416)				
Brussels	-0.15***		-0.09	0.130	0.315***	0.466*	4	1	1.087	0.596
	(0.047)		(0.082)	(0.087)	(0.076)	(0.238)				
Leuven	-0.21***		-0.39***	0.185	0.329***	-0.01	3	3	0.269	0.485
	(0.072)		(0.114)	(0.192)	(0.109)	(0.385)				
Nivelles	-0.18***		-0.32***	0.505***	0.207***	1.06***	1	1	-2.010**	0.504
	(0.047)		(0.076)	(0.147)	(0.078)	(0.339)				
Dendermonde		-0.36***	-0.03	-0.18	0.184**	0.621	1	1	1.177	0.386
		(0.084)	(0.107)	(0.120)	(0.080)	(0.427)				
Ghent			-0.59***	0.564***	0.136	0.616	2	2	0.924	0.344
			(0.110)	(0.140)	(0.160)	(0.441)				
Namur	-0.15***		-0.43***	0.288**	0.243***	0.689*	1	1	0.602	0.481
	(0.034)		(0.090)	(0.139)	(0.092)	(0.379)				

Note: The table reports estimates based on the price equations $\Delta p_{it} = \phi_{is}(p_{i,t-1} - p^s_{i,t-1}) + \phi_{i0}(p_{i,t-1} - p_{0,t-1}) + \alpha_i + \sum_{l=1}^{k_{i\beta}} \beta_{il}\Delta p_{i,t-l} + \sum_{l=1}^{k_{i\gamma}} \gamma_{il}\Delta\bar{p}^s_{i,t-l} + \sum_{l=1}^{k_{i\kappa}} \kappa_{il}\Delta p_{0,t-l} + c_{i0}\Delta p_{0t} + \epsilon_{it}$,for $i = 1, 2, ..., N$. For $i = 0$, denoting the Antwerp price equation, we have additional a priori restrictions, $\phi_{00} = c_{00} = 0$. "EC1", "EC2", "Own lag effects", "Neighbor lag effects" and "Dominant region contemporaneous effects" relate to the estimates of ϕ_{i0}, ϕ_{is}, β_{i1}, γ_{i1} and κ_{i0}. Standard errors are shown in parenthesis. *** signifies that the test rejects the null at 1% level, ** at the 5% level, and * at the 10% level. Wu-Hausman is the t-ratio for testing $H_0 : {}_i = 0$ in the augmented regression $\Delta p_{it} = \phi_{is}(p_{i,t-1} - p^s_{i,t-1}) + \phi_{i0}(p_{i,t-1} - p_{0,t-1}) + \alpha_i + \sum_{l=1}^{k_{i\beta}} \beta_{il}\Delta p_{i,t-l} + \sum_{l=1}^{k_{i\gamma}} \gamma_{il}\Delta\bar{p}^s_{i,t-l} + \sum_{l=1}^{k_{i\kappa}} \kappa_{il}\Delta p_{0,t-l} + \kappa_{i0}\Delta p_{0t} + \lambda_i\hat{\epsilon}_{0t} + \epsilon_{it}$, where ϵ_{0t} is the residual of the Antwerp price equation. In selecting the lag orders, $k_{i\beta}$, $k_{i\gamma}$ and $k_{i\kappa}$ the maximum lag-order is set to 4. All the regressions include an intercept term, 3 seasonal dummies and an additional dummy-variable to account for the change in the classification process of ADSEI in 2005.

Table 8: Estimation Results of Region Specific House Price Diffusion Equation with Antwerp as the Dominant Region (1973Q1-2011Q3) (Part 2)

			Lag-orders $\{\hat{k}_{i\beta},\hat{k}_{i\gamma}\}$ selected by BIC							
Regions	EC1 ($\hat{\phi}_{i0}$)	EC2 ($\hat{\phi}_{is}$)	Own Lag Effects ($\hat{\beta}_{i1}$)	Neighbor Lag Effects ($\hat{\gamma}_{i1}$)	Dom. Region ($\hat{\kappa}_{i0}$)	($\hat{\psi}_{i0}$)	$\hat{k}_{ia}$	$\hat{k}_{ib}$	Wu-Hausman Statistics	R^2
Bruges	-0.17***	-0.20**	-0.20**	-0.02	0.422***	1.05***	1	1	0.924	0.521
	(0.048)	(0.085)	(0.092)	(0.104)	(0.095)	(0.386)				
Kortrijk	-0.16***		-0.26**	-0.04	0.229**	0.403	2	1	1.621	0.352
	(0.031)		(0.108)	(0.126)	(0.097)	(0.364)				
Veurne		-0.71***	-0.03	-0.37**	0.007	0.427	1	1	0.982	0.386
		(0.137)	(0.096)	(0.178)	(0.142)	(0.502)				
Oudenaarde		-0.43***	-0.27***	-0.11	0.094	-0.15	1	1	-0.028	0.389
		(0.094)	(0.090)	(0.232)	(0.146)	(0.551)				
Charleroi		-0.34***	-0.15	-0.19	0.188***	0.307	1	1	0.949	0.544
		(0.054)	(0.094)	(0.121)	(0.069)	(0.269)				
Tournai		-0.35***	-0.30***	0.173	0.275***	0.492	2	1	-0.407	0.500
		(0.080)	(0.096)	(0.171)	(0.084)	(0.351)				
Lège		-0.33***	-0.25**	0.116	-0.02	0.631*	1	1	-0.509	0.563
		(0.059)	(0.101)	(0.116)	(0.080)	(0.334)				
Verviers	-0.17***		-0.36***	0.214*	0.314**	0.449	2	1	-0.451	0.472
	(0.046)		(0.093)	(0.119)	(0.130)	(0.571)				
Hasselt		-0.34***	-0.30**	-0.04	0.324***	0.378	1	1	0.304	0.421
		(0.104)	(0.126)	(0.126)	(0.103)	(0.621)				
Arlon	-0.20***	-0.29**	-0.15	0.124	0.327***	0.943	2	1	-0.316	0.425
	(0.058)	(0.132)	(0.128)	(0.178)	(0.126)	(0.705)				
Dinant	-0.11**	-0.33**	-0.23**	0.298	0.010	1.02**	1	1	-0.565	0.425
	(0.052)	(0.137)	(0.104)	(0.186)	(0.122)	(0.472)				

Note: Standard errors are shown in parenthesis. *** signifies that the test rejects the null at 1% level, ** at the 5% level, and * at the 10% level. All the regressions include an intercept term, 3 seasonal dummies and an additional dummy-variable to account for the change in the classification process of ADSEI in 2005.

Table 9: Estimation Results of Region Specific House Price Diffusion Equation with Antwerp as the Dominant Region and Cross-Linguistic and Non-Cross-Linguistic Border Dynamics (1980Q1-2011Q1) (Part 1)

Regions	EC1 ($\hat{\phi}_{i0}$)	EC2 ($\hat{\phi}_{iso}$)	EC3 ($\hat{\phi}_{is_c}$)	Own Lag Effects ($\hat{\beta}_{i1}$)	Intra-Regional ($\hat{\gamma}_{i1}$)	Inter-Regional ($\hat{\delta}_{i1}$)	Dom. Region ($\hat{\kappa}_{i0}$)	Real GDP ($\hat{\psi}_0$)	$\hat{k}_{ia}$	$\hat{k}_{ib}$	$\hat{k}_{ic}$	Wu-Hausman Statistics	R^2
Antwerp				-0.29***	0.349***			0.907***	1	1			0.328
				(0.093)	(0.108)			(0.347)					
Mechelen	-0.21***			-0.26**	0.406***		0.398***	-0.25	1	1		-0.291	0.444
	(0.066)			(0.113)	(0.144)		(0.114)	(0.398)					
Turnhout		-0.19***		-0.26***	0.337***		0.363***	0.556	2	1		0.870	0.469
		(0.050)		(0.087)	(0.126)		(0.097)	(0.417)					
Brussels	-0.15***			-0.08	-0.01	0.140**	0.312***	0.445*	4	1	1	0.783	0.597
	(0.046)			(0.088)	(0.086)	(0.070)	(0.074)	(0.238)					
Leuven	-0.25***			-0.27***	-0.16	0.094	0.335***	0.060	1	4	1	0.354	0.479
	(0.076)			(0.089)	(0.128)	(0.176)	(0.116)	(0.384)					
Nivelles	-0.17***			-0.33***	0.191	0.300***	0.215***	1.05***	1	1	1	-2.212**	0.514
	(0.048)			(0.076)	(0.126)	(0.094)	(0.077)	(0.340)					
Dendermonde		-0.32***		-0.05	-0.15		0.182**	0.616	1	1		1.214	0.375
		(0.077)		(0.106)	(0.122)		(0.081)	(0.435)					
Ghent				-0.59***	0.524***		0.133	0.614	2	2		0.960	0.337
				(0.109)	(0.133)		(0.161)	(0.441)					
Namur	-0.15***			-0.42***	0.230*		0.254***	0.692*	1	1		0.380	0.476
	(0.034)			(0.089)	(0.122)		(0.093)	(0.379)					

Note: The table reports estimates based on the price equations $\Delta p_{it} = \phi_{is_o}(p_{i,t-1} - p^{s_o}_{i,t-1}) + \phi_{is_c}(p_{i,t-1} - p^{s_c}_{i,t-1}) + \phi_{i0}(p_{i,t-1} - p_{0,t-1}) + \alpha_i + \sum_{l=1}^{k_{i\beta}} \beta_{il}\Delta p_{i,t-l} + \sum_{l=1}^{k_{i\gamma}} \gamma_{il}\Delta\bar{p}^{s_o}_{i,t-l} + \sum_{l=1}^{k_{i\delta}} \delta_{il}\Delta\bar{p}^{s_c}_{i,t-l} + \sum_{l=1}^{k_{i\kappa}} \kappa_{il}\Delta p_{0,t-l} + c_{i0}\Delta p_{0t} + \epsilon_{it}$,for $i = 1, 2, ..., N$. For $i = 0$, denoting the BCR equation, we have additional a priori restrictions, $\phi_{00} = c_{00} = 0$. "EC1", "EC2", "EC3", "Own lag effects", "Intra-regional", "Inter-regional" and "Dominant Region contemporaneous effects" relate to the estimates of ϕ_{i0}, ϕ_{is_o},ϕ_{is_c}, β_{i1}, γ_{i1}, δ_{i1} and κ_{i0}. Standard errors are shown in parenthesis. *** signifies that the test rejects the null at 1% level, ** at the 5% level, and * at the 10% level. Wu-Hausman is the t-ratio for testing $H_0 : {}_i = 0$ in the augmented regression $\Delta p_{it} = \phi_{is_o}(p_{i,t-1} - p^{s_o}_{i,t-1}) + \phi_{is_c}(p_{i,t-1} - p^{s_c}_{i,t-1}) + \phi_{i0}(p_{i,t-1} - p_{0,t-1}) + \alpha_i + \sum_{l=1}^{k_{i\beta}} \beta_{il}\Delta p_{i,t-l} + \sum_{l=1}^{k_{i\gamma}} \gamma_{il}\Delta\bar{p}^{s_o}_{i,t-l} + \sum_{l=1}^{k_{i\delta}} \delta_{il}\Delta\bar{p}^{s_c}_{i,t-l} + \sum_{l=1}^{k_{i\kappa}} \kappa_{il}\Delta p_{0,t-l} + c_{i0}\Delta p_{0t} + \lambda_i\hat{\epsilon}_{0t} + \epsilon_{it}$, where ϵ_{0t} is the residual of the Antwerp price equation. In selecting the lag orders, $k_{i\beta}$, $k_{i\gamma}$ and $k_{i\kappa}$ the maximum lag-order is set to 4. All the regressions include an intercept term, 3 seasonal dummies and an additional dummy-variable to account for the change in the classification process of ADSEI in 2005.

Table 9: Estimation Results of Region Specific House Price Diffusion Equation with Antwerp as the Dominant Region and Cross-Linguistic and Non-Cross-Linguistic Border Dynamics (1980Q1-2011Q1) (Part 2)

Regions	EC1 ($\hat{\phi}_{i0}$)	EC2 ($\hat{\phi}_{iso}$)	EC3 ($\hat{\phi}_{is_c}$)	Own Lag Effects ($\hat{\beta}_{i1}$)	Intra-Regional ($\hat{\gamma}_{i1}$)	Inter-Regional ($\hat{\delta}_{i1}$)	Dom. Region ($\hat{\kappa}_{i0}$)	Real GDP ($\hat{\psi}_0$)	$\hat{k}_{ia}$	$\hat{k}_{ib}$	$\hat{k}_{ic}$	Wu-Hausman Statistics	R^2
Bruges	-0.16***	-0.21**		-0.20**	-0.03		0.419***	1.06***	1	1		1.107	0.523
	(0.047)	(0.082)		(0.088)	(0.101)		(0.094)	(0.385)					
Kortrijk	-0.14***		-0.17*	-0.12	-0.13	-0.04	0.212**	0.554	1	1	1	1.820*	0.351
	(0.032)		(0.097)	(0.113)	(0.104)	(0.107)	(0.098)	(0.381)					
Veurne		-0.71***		-0.03	-0.38**		0.001	0.442	1	1		1.045	0.391
		(0.134)		(0.095)	(0.177)		(0.141)	(0.498)					
Oudenaarde		-0.45***		-0.26***	-0.10	-0.05	0.075	-0.24	1	1	1	0.039	0.418
		(0.091)		(0.092)	(0.220)	(0.138)	(0.144)	(0.536)					
Charleroi		-0.28***		-0.17*	-0.18		0.195***	0.290	1	1		1.045	0.536
		(0.045)		(0.093)	(0.114)		(0.069)	(0.271)					
Tournai		-0.22**		-0.38***	0.296*	0.011	0.249***	0.162	2	4	1	-1.495	0.597
		(0.091)		(0.117)	(0.169)	(0.090)	(0.084)	(0.369)					
Liège		-0.16**	-0.22***	-0.18*	0.008	-0.04	-0.04	0.547	1	1	1	-0.609	0.555
		(0.078)	(0.056)	(0.104)	(0.102)	(0.076)	(0.082)	(0.337)					
Verviers	-0.17***			-0.38***	0.302**		0.290**	0.459	2	1		-0.204	0.474
	(0.044)			(0.090)	(0.125)		(0.132)	(0.566)					
Hasselt		-0.31***		-0.33***	-0.10	-0.04	0.298***	0.263	1	1	1	0.017	0.442
		(0.085)		(0.117)	(0.106)	(0.097)	(0.106)	(0.601)					
Arlon	-0.20***	-0.31**		-0.15	0.128		0.324***	0.926	2	1		-0.131	0.428
	(0.058)	(0.133)		(0.127)	(0.178)		(0.125)	(0.705)					
Dinant	-0.09*	-0.47***		-0.18*	0.225		0.003	0.983**	1	1		-0.267	0.439
	(0.049)	(0.157)		(0.109)	(0.202)		(0.124)	(0.457)					

Note: Standard errors are shown in parenthesis. *** signifies that the test rejects the null at 1% level, ** at the 5% level, and * at the 10% level. In selecting the lag orders, $k_{i\beta}$, $k_{i\gamma}$ and $k_{i\kappa}$ the maximum lag-order is set to 4. All the regressions include an intercept term, 3 seasonal dummies and an additional dummy-variable to account for the change in the classification process of ADSEI in 2005.

Figure 4: Generalized spatio-temporal Impulse Response Functions and their Bootstrapped Confidence Intervals (horizon = 50)