ETLA

ELINKEINOELÄMÄN TUTKIMUSLAITOS
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
Lönnrotinkatu 4 B 00120 Helsinki Finland Tel. 358-9-609 900
Telefax 358-9-601 753 World Wide Web: http://www.etla.fi/

Keskusteluaiheita – Discussion papers

No. 979

Elias Oikarinen*

THE DIFFUSION OF HOUSING PRICE MOVEMENTS FROM CENTRE TO SURROUNDING AREAS**

* GS-fellow, Turku School of Economics and Business Administration & FDPE
elias.oikarinen@tukkk.fi, Tel. +358 40 5871943

** The author is grateful for comments received at the ACE Seminar in Lieto, the FDPE econometrics and computational economics seminar at the Helsinki Center for Economic Research, at the XXVII Annual Meeting of Finnish Economists in Maarianhamina and at the twenty-first American Real Estate Society Meeting in Santa Fe, New Mexico. Furthermore, the author is indepted to Professor Paavo Okko and Professor Matti Virèn for their valuable comments. Financial support from Jenny and Antti Wihuri Foundation, Kiinteistösäätiö, Kluuvi Foundation, Liikesivistysrahasto, the Real Estate Education and Training Institute in Finland and Yrjö Jahnsson Foundation is gratefully acknowledged. The usual disclaimer applies.

ISSN 0781-6847 25.04.2005

OIKARINEN, Elias, **THE DIFFUSION OF HOUSING PRICE MOVEMENTS FROM CENTRE TO SURROUNDING AREAS.** Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, Research Institute of the Finnish Economy, 2005, 36 p. (Discussion Papers, ISSN 0781-6847; no. 979).

ABSTRACT: Previous empirical research shows that there are strong interrelationships between regional housing markets in Finland. There are many reasons why housing price changes in central areas may lead housing price changes in the surrounding areas. These reasons include structural differences and economic interdependence between regions as well as informational factors. This paper studies the hypothesis that there is a lead-lag relation between housing price movements in central and surrounding areas. Vector autoregressive and vector error-correction models using quarterly data from the Finnish housing markets from 1987 to 2004 are estimated. The results show that housing price changes diffuse first from the Helsinki Metropolitan Area, the main economic centre in Finland, to the regional centres and then to peripheral regions surrounding them. Inside the Helsinki Metropolitan Area, instead, housing price changes in the suburbs have Granger caused price movements in the city centre.

Keywords: Housing, dynamics, Granger causality, cointegration, regions

OIKARINEN, Elias, **THE DIFFUSION OF HOUSING PRICE MOVEMENTS FROM CENTRE TO SURROUNDING AREAS.** Helsinki: ETLA, Elinkeinoelämän Tutkimuslaitos, Research Institute of the Finnish Economy, 2005, 36 s. (Discussion Papers, ISSN 0781-6847; no. 979).

TIIVISTELMÄ: Aikaisemmissa empiirisissä tutkimuksissa on havaittu, että Suomen alueellisten asuntomarkkinoiden välillä on selviä keskinäisiä riippuvuussuhteita. On olemassa useita syitä, joiden perusteella voidaan ennakoida keskusalueen asuntohintamuutosten ennakoivan asuntohintojen liikkeitä ympäröivillä seuduilla. Tällaisia tekijöitä ovat erityisesti aluetalouksien rakenteelliset erot ja keskinäiset riippuvuudet sekä asuntomarkkinoita koskevan informaation epätäydellisyys ja kalleus. Tämän tutkimuksen tarkoituksena on selvittää empiirisesti, seuraavatko asuntohintamuutokset ympäröivillä alueilla viiveellä asuntohintojen liikkeitä keskusalueella. Tutkimuksessa estimoidaan vuodesta 1987 vuoteen 2004 ulottuvien Suomen alueellisia asuntomarkkinoita koskevien hedonisten hintaindeksien pohjalta alueellisten asuntohintojen dynaamisia riippuvuussuhteita kuvaavia VAR-malleja sekä vektorivirheenkorjausmalleja. Tulosten mukaan asuntohintamuutokset leviävät ensin pääkaupunkiseudulta ympäryskuntiin sekä alueellisiin keskuksiin ja sen jälkeen edelleen muille alueille. Pääkaupunkiseudun sisällä sen sijaan esikaupungin hintamuutokset ovat edeltäneet Helsingin keskustan hintakehitystä.

Asiasanat: Asuntomarkkinat, dynamiikka, kausaalisuus, yhteisintegroituvuus

1 INTRODUCTION

Previous research has shown that price movements, i.e. capital returns, in the Finnish housing markets as well as in several other countries' housing markets are predictable using historical housing price data. Nevertheless, there still appears to be little applied work on the regional housing price dynamics, despite the fact that regional housing price movements are likely to be of importance for consumer expenditure, the labour market and housing portfolio allocation. Furthermore, the predictability of price movements can be used, for example, to optimally time completion of new dwellings or transactions concerning second-hand dwellings. The dynamics of housing price movements are also of interest because they throw some light on the operation of the housing market.

It is often assumed that housing price movements diffuse from the economic centres to the surrounding regions. This view is supported by a number of empirical studies examining regional housing price dynamics (see e.g. Meen 1996, Berg 2002). The reasoning behind the leading role of main economic centres has usually been based on an assumption that business cycles hit economic centres first and more peripheral areas later. There are, however, also other reasons, especially informational factors, that may cause or strengthen the leading role of main economic regions. Inside a metropolitan area, however, it is difficult to say straightforwardly whether the centre is likely to lead surrounding areas or *vice versa*. In any case, proper empirical analysis is needed to examine whether there are notable lead-lag relations between housing price movements in the centre and surrounding areas.

In this paper the dynamics between regional housing markets in Finland are further examined. The relationships between housing price movements in central and surrounding areas are of a particular interest in the analysis. The purpose is to study empirically if housing price changes diffuse from the central areas to the more peripheral regions, i.e. if housing price changes in the central areas lead housing price movements in the surrounding areas. This is done by employing vector autoregressive (VAR) and vector error-correction models (VECM). The data used in the analysis is quarterly hedonic housing price indices from 1987 to 2004 concerning different housing markets in Finland. First, the dynamics between the centre and the other parts of the Helsinki Metropolitan Area (HMA) are examined. Second, the hypothesis that housing price changes in the other parts of the country follow those of the HMA is analysed. Third, lead-lag relations between some regional centres and provinces surrounding them are also investigated.

In the next section the potential reasons for lead-lag relation between housing markets in centre and surrounding areas are discussed. After this the paper proceeds with a review of relevant literature. In the third part the data is delineated, after which the methodology used in the empirical analysis is described. This is followed by a section reporting results from the econometric analysis. In the end conclusions are derived.

2 DYNAMICS OF REGIONAL HOUSING PRICE MOVEMENTS THEORETICAL CONSIDERATION

Housing price levels may differ substantially between different regions, and different regional housing markets can be viewed as separate assets. Nonetheless, housing price changes are likely to correlate significantly between regional markets. In perfect capital markets there are no lead-lag relationships between assets. In real estate markets, however, substantial transaction costs, thin markets, lack of centralised information gathering and lengthy delays in information availability may account for lagged relationships in price movements even in the absence of irrationality. In this paper particular interest is laid on the house price dynamics between the centre areas and regions surrounding them. There are a number of reasons why it may be assumed that housing price movements in an economic centre lead housing price changes in surrounding areas. These reasons include structural differences and economic interdependence between regions as well as informational factors.

One likely reason to cause lead-lag relationship in housing price movements between centre and surrounding areas is regional differences in the timing of the business cycles. Business cycles usually first hit main economic centres of a country and centres of metropolitan areas. The likelihood that the central areas react first to a macro level shock is increased by the fact that financial services are usually concentrated in the centres of the major cities — financial sector is often the first one to respond to macro shocks. As a shock causes the number of jobs and the level of income to change the housing markets react accordingly. With lag the shock spreads to the surrounding areas.[1] This suggests that housing price changes in the centre area proxies for macroeconomic news that later affect also more peripheral regions.

Another explanation for possible lead-lag relation between central and peripheral areas can be found by applying the idea introduced originally by Grossman and Stiglitz (1976). The idea is based on the assumption that there are both informed and uninformed actors in the market. In this case uninformed refers to agents who do not have even publicly available information or at least do not know how the information should affect housing prices. The more there are informed actors in the market the faster the prices are likely to fully react to a shock. Assume, for example, new information that positively affects the expectations of future nationwide employment and income. Having the information and knowing how it should affect housing demand in the future informed investors are willing to buy dwellings at a higher price. Similarly of course, informed agents raise asking prices for the dwellings they are offering for sale. If all the agents in the market are informed, the price level should adjust to the new information set immediately. However, it is reasonable to believe that in all the housing markets there are a significant number of uninformed actors. For the uninformed agents it takes time before they perceive the change in the market conditions and consequently increase asking prices or are willing to pay more for dwellings. The bigger the share of the uninformed agents in the market the longer the adjustment process is likely to last. The share of informed (i.e. mainly institutional) investors is usually substantially

---

[1] Naturally there are also macro shocks that should affect housing prices all over the country simultaneously. This kind of shock is, for example, change in the level of real interest rates.

larger in the central areas than in more peripheral regions. Therefore, housing prices in central areas are likely to react faster to a shock.

Findings supporting the role of informational asymmetries in creating regional lead-lag relations are reported e.g. by Clapp et al. (1995). They also suggest that, because information production is subject to positive scale economies, higher population density should foster more, better and prompter information also concerning housing markets. With time this information spreads also to more sparsely populated regions. Hence, it is expected that housing price movements in densely populated centre areas lead price changes in the more peripheral regions.

The reasoning above is based on differences between economic structures or composition and density of the actors in the housing market in different areas, and adjustment to macroeconomic shocks are seen as the driving force for lead-lag relation between housing price movements in the centre and surrounding areas. It is sometimes also possible that price change in one area is at least partly caused by price change in another area. This is possible concerning two areas located relatively close to each other, i.e. areas whose dwellings are relatively close substitutes for each other. Consider for example the effect of migration. Migrants are typically young adults who want to live as close to the activities of the city centre as possible. Hence, migration to a metropolitan area may augment housing demand especially in the centre. Nevertheless, housing in the areas surrounding the centre is often a relatively close substitute for the dwellings located in the centre. As the housing price level rises in the central areas relative to the surrounding regions, more of the dwellers in the centre as well as more of the new migrants are willing to move to suburbs where they can get larger dwellings with the same money.[2] This causes price level to increase in the surrounding areas with lag. In frictionless markets the length of the lag would be negligible. In housing markets, however, high transaction costs, low liquidity and lacking information may lead to substantial lags in the diffusion of housing price movements.

On the other hand, causal relation between nearby areas can also be the other way around. This can be the case for example if, during a particular period, new employment opportunities have grown faster in the suburbs than in the centre. Workers usually want to live near the employment centres to avoid long commutes. Hence, demand for housing is increased in the areas where the number of jobs grows substantially. However, there are people, e.g. pensioners and students, for whom it is not particularly important to live close to the employment centres. After the relative price level has risen in the suburban areas with high employment growth, the relative attractiveness of the centre areas increases for these dwellers. Thus, the substitution effect may increase housing prices in the centre with lag. Similarly, if there is a recession in some industries that have a large number of jobs in the suburbs, housing price decrease in surrounding areas may lead price drop in the centre. Which way the possible causal relationship has gone during a particular period of time, is an empirical question. In any case, the kind of interdependence between nearby housing markets explained above can generate also a cointegrating relationship between the markets. In other words, there may be a long-run equilibrium relationship between the markets so that price levels in the two areas cannot diverge too much from each other.

---

[2] Empirical evidence in support of this kind of behavior is reported e.g. by Thomas (1993). Furthermore, using Finnish data Hämäläinen and Böckerman (2004) found expectedly that housing prices affect net migration negatively.

The kind of causal relation between housing prices in different regions explained above cannot, however, be assumed to work between areas far away from each other, i.e. between areas whose dwellings are not substitutes for each other. Nevertheless, it may also be possible that price change in one area causes price change in an area geographically far away from it. It is obvious that in the long run housing prices must reflect market fundamentals. In the short run, however, flawed beliefs concerning the fundamental value of housing as well as speculation in the market based on expected price changes are likely to have a significant effect on housing price movements. Most of the actors in regional housing markets are not likely to have knowledge concerning the fundamental price level. Because achieving such knowledge often involves relatively high costs, for many actors it may be rational to take some reference point or benchmark based on which the "right" price level is evaluated. A prominent reference point is the national housing price index. If, for example, the national price index has risen much faster than a regional index, many actors in the regional market are likely to form positive expectations concerning price growth in the region, even if no shock affecting regional housing market has actually occurred. In fact, actors in the regional market may mistakenly assume that the growth in the nationwide index has been caused by a macro shock that will affect regional economy later. The expectations then fulfil themselves. Hence, regional price movements follow national price changes with lag.

This kind of short-term interdependence between regional housing prices may be strengthened by real estate agents. Having perceived in the past that changes in the regional housing price level often follow some reference index with lag, it is probable that real estate agents base their expectations on the movements of the reference index. In the long horizon, as already mentioned, the price level has to be based on the fundamental factors, however.

In the Finnish case it seems possible that the kind of causal relationship explained above could generate short-term lead-lag relation between the HMA and the other regions in Finland. This assumption is based on the fact that the national housing price figures are dominated by housing in the HMA. Furthermore, the media usually concentrate on reporting price movements in the HMA together with the national figures. So, for many actors in the market the price movements in the HMA are the ones they perceive.

The endogeneity of business cycles with respect to housing wealth can strengthen causal relationship between relatively distant areas to some extent. This is due to the "wealth effect", i.e. the causal effect of exogenous changes in wealth upon consumption behaviour. Case et al. (2001) show, relying on panel of 14 countries, that the effect of housing wealth upon consumption is statistically significant and appears to be more important than the wealth effect of stock market. The results of Benjamin et al. (2004) concerning US data are in accordance with Case et al. Because of the wealth effect of housing, higher housing prices lead to higher level of consumption. Growing consumption in a given area leads to growing demand on products imported from the other areas. Thus, part of the consumption growth caused by the wealth effect "leaks" to other regions. This, in turn, causes employment and income to rise in the other areas, which leads to growing demand for housing. Through this channel housing price rise in one area can somewhat increase price level in another area with lag. It is reasonable to believe that in Finland the only area economically large enough to create this kind of notable spillover effects is the HMA.

Lead-lag relationships between regional housing prices do not necessarily imply that the markets are informationally inefficient, at least concerning all public information, i.e. semi-strong form informational efficiency. Information concerning a macro level shock comes into public knowledge often several months after the shock has occurred. Also housing price statistics and statistics concerning demographic factors are published with lag. Therefore, actors in the market cannot often use relevant information to predict price level in the next quarter. The ability to predict would cause the price level in an efficient market to change already in the current quarter. Then, of course, there would be no lead-lag relationship or at any rate it should be weak. Informational inefficiency is implied, however, if prices in surrounding areas follow those of central areas with a lag of several quarters. Furthermore, markets are obviously informationally inefficient if lead-lag relation is strengthened by a small number of informed actors in some markets.

3 PREVIOUS RESEARCH

Research on housing price dynamics between different regions has so far been relatively limited. Concerning regional housing price dynamics in Finland Booth et al. (1996) found surprisingly that Tampere is the leading city in spite of the fact that Helsinki is by far the most important economic centre in Finland. Using longer time series Kuosmanen (2002), however, found evidence in support of the leading role of Helsinki. Similarly, according to Berg (2002) the housing price changes in the biggest city in Sweden, Stockholm, lead house price movements in the other parts of Sweden. The findings of Kuosmanen and Berg are in accordance with the assumption that housing price movements in the biggest centres lead housing price changes in the other areas. Both of these papers concentrate on examining the short-run dynamics between the cities by employing vector autoregressive models for price changes.

In neither of the studies mentioned above the possible existence of long-run dynamics, i.e. a long-run equilibrium relationships between different regions, was considered. The results of Oikarinen and Asposalo (2004), however, indicate that there are cointegrating relationships between housing prices in a number of areas in Finland, especially inside the HMA. Based on quarterly data from 1985 to 2002 Oikarinen and Asposalo found some long-run equilibrium relationships also between different cities in Finland. The article did not examine lead-lag relations either between the HMA submarkets or between the cities, though.

Long-run equilibrium relationships between regional real estate prices have been detected also in studies using data from other countries. MacDonald and Taylor (1993) found cointegrating relationships between housing prices and Tarbert (1998) between commercial property prices, in different areas in the UK. The Results of Meen (1996) are congruent with MacDonald and Taylor. Futhermore, Meen suggests that housing prices in the main economic region, i.e. South-East, leads prices in the other UK regions. Causality is not formally tested, however. There is also relevant research using data from Australia. Smyth and Nandha (2003) reported causalities and long-term equilibrium relationships between Australian capital cities. Wilson et al. (2003), in turn, found cointegration between commercial property prices in different regions in Australia. Utilising Engle-Granger and Gregory-Hansen tests Wilson et al. also showed that allowing for unknown structural breaks it is possible to find many more long-term interrelationships than when ignoring the possibility of structural breaks. That is, ignoring structural changes may lead to not finding a cointegrating relationship even though there really is one. In addition, Pollakowski and Ray (1997) found that subnational house price changes in the US are interrelated. They did not study long-term interdependences, however.

Some studies have examined short-term housing price dynamics also inside metropolitan areas. Clapp and Tirtiroglu (1994) using data from Hartford and Clapp et al. (1995) and Dolde and Tirtiroglu (1997) employing data from Hartford and San Francisco showed that housing price changes tend to diffuse throughout a metropolitan area. All these papers related the dynamics to imperfect information and to the informational content of price levels and movements in nearby areas. The analysis of Clapp et al. suggested that information diffusion takes up to two quarters even inside a single metropolitan area and population density is likely to quicken the information diffusion. Furthermore, some of the evidence of Clapp et al. and Dolde and Tirtiroglu seem to be consistent with explanations that admit some rational elements in regional housing price dynamics.

In summary, there has been some research on short- and long-term housing price dynamics between regions but none of the studies, at least studies mentioned above, has specifically examined causal relationships between central and surrounding regions also allowing for possible long-run interdependences. In addition, in the cointegration tests studying regional price dynamics the specification of deterministic variables has not been done rigorously. An exception to this is the paper of Oikarinen and Asposalo. In many cases the determination of deterministic variables may be of great significance when doing inferences concerning the existence of long-term equilibrium relationships. This paper brings further evidence in the area by concentrating on examining causal relations between regions also in the VECM framework and by justifying the use of VECMs with different deterministic factors. In addition, this paper brings evidence regarding housing price dynamics within a single metropolitan area.

4 DATA DESCRIPTION

The housing price indices used in the study are based on the quarterly hedonic price indices constructed by Statistics Finland. The indices cover a period from 1/1987 to 4/2004 and are grounded on prices of flats sold in the secondary market. The data are based on price information gathered by the tax authorities in connection with the asset transfer tax. In this paper only real indices and returns are used. Hence, the indices provided by Statistics Finland have been deflated using the cost of living index. Furthermore, as long-horizon investors are assumed, natural log returns are used throughout the paper.

First, two indices describing housing price development within the HMA are used. These indices are for the centre of the HMA and for the other parts of the HMA (OHMA). Second, four indices are employed to analyse the price diffusion from the HMA to the rest of the country: the HMA, the Satellites, other growth centres (OGC) in Finland and the rest of Finland (ROF).[3] Because Statistics Finland does not offer separate OHMA, OGC or ROF indices, these indices have been constructed for the needs of this study based on the hedonic indices that Statistics Finland does provide. The method of constructing the OHMA,

---

[3] The centre of Helsinki is the area Helsinki-1 defined by Statistics Finland. Other parts of the HMA cover the rest of Helsinki together with Espoo, Kauniainen and Vantaa. The Satellites refer to towns surrounding the HMA. These towns are Hyvinkää, Järvenpää, Kerava, Riihimäki, Kirkkonummi, Nurmijärvi, Sipoo, Tuusula and Vihti. Other growth centres include Jyväskylä, Oulu, Tampere and Turku. The rest of the country covers all the areas in Finland other than those mentioned above.

OGC and ROF series is explained in the Appendix. These series may not correspond perfectly to the actual price movements in the areas. Nevertheless, they are the best approximation available and the potential differences from the actual price movements are likely to be small. Finally, indices for four provincial centres and the provinces surrounding them are applied to study the dynamics between the centres and peripheral regions within provinces. The four centres and corresponding provinces are Turku - South West Finland (SWF), Tampere - Tampere Region (TR), Jyväskylä - Central Finland (CF) and Oulu - Oulu Region (OR).[4]

All the real price indices except for the index for the HMA are presented in Figures 1 and 2. The index for the HMA follows the OHMA index closely.

The overheating of the Finnish housing markets at the end of the 1980s can be seen well in Figure 1. At the turn of the decade the bubble burst causing a sharp drop in the housing prices. The decrease in the price level was strengthened by a severe recession of the Finnish economy. The bottom of the depression was reached in 1993 and eventually in 1996 housing prices started to rise again together with the Finnish economy. Although the general pattern of the house price movements was the same across the country, there were substantial differences in the size of the bubble in different areas. In general, in the HMA and its surroundings the housing markets have been more cyclical than in the other parts of the country. In the Satellites the real housing price level was at its highest over 70 percent higher than in 1/87 and in the bottom the real prices were 60 percent lower than in 1/89. The ROF index, instead, was at its height less than 50 percent higher than at the beginning of the sample period and the real price drop from the top of the bubble to the bottom was 46 percent.

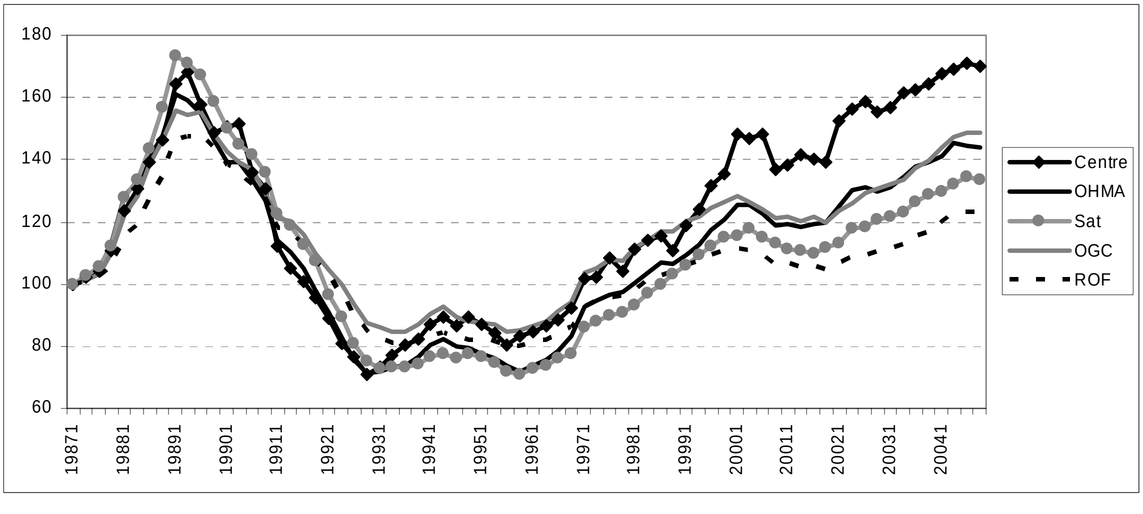

Figure 1 **The real housing price indices for the centre of the HMA, the OHMA, the Satellites, the OGC and the ROF**

---

[4] Statistics Finland does not publish the indices for surrounding provinces, i.e. the provinces excluding their capital cities. The reason for this lies in the reliability of those indices – the provinces outside their capital cities are geographically relatively large areas with relatively small number of observations per quarter. The provinces included in this analysis are the largest ones in population and the number of transactions (outside of the Helsinki Region). Hence, it is likely that the “rest of the province” –indices are reliable enough to study the existence of lead-lag relations between provincial centres and surrounding areas.

Since the midway of the 1990s real housing prices have increased substantially all over the country. Regional housing price development has diverged somewhat, however. This divergence has mainly been due to increased migration from peripheral areas to the HMA and to a couple of regional centres. At the beginning of the sample period regional price indices moved together because the price shocks in all the areas where largely caused by macro factors. In any case, to have sufficient number of degrees of freedom the sample period is not split in the analysis.

The fact that prices have grown much faster in the centre of the HMA than in the other parts of Finland is probably mainly due to the fact that housing supply in the area cannot properly adjust to the growing demand because of the lack of free space. Also the differences in standard deviations (see Table 1) can be explained, at least partly, by differences in the flexibility of housing supply. In the centre of the HMA quarterly standard deviation has been over four percentage points higher than in the ROF where housing supply is more flexible than in the other areas.

Figure 2 shows that in the provincial centres housing prices have grown much faster than in the peripheral regions. This is not surprising, since population growth rate has been much faster in each of the centres than in the peripheral areas and building land is scarcer resource in the centres. On the other hand, volatility of capital returns has been lower in the peripheral areas.

Descriptive statistics concerning the real housing price changes in each of the areas are presented in **Table 1**. According to the Jarque-Bera test normality cannot be rejected in any of the series. The Table reveals, however, that the price change series are highly autocorrelated. All the first order autocorrelation coefficients are significant in the one percent level of significance, except for the peripheral areas in Central Finland and in the Oulu Region. Autocorrelation in housing price movements does not, nevertheless, necessarily mean that the markets are informationally inefficient (see e.g. Poterba 1984).

Table 1 Descriptive statistics of the quarterly real housing price change

Area	Mean (annualised)	Standard deviation (annualised)	Jarque-Bera (p-value)	First order auto-correlation[5]
Centre of the HMA	.030	.105	.181	.446
Other parts of the HMA	.021	.088	.346	.722
Whole HMA	.022	.088	.376	.709
Satellites	.016	.089	.140	.721
Other growth centres	.023	.072	.465	.666
Rest of Finland	.012	.062	.280	.744
Turku	.017	.079	.391	.538
Rest of South West Finland	.006	.057	.583	.558
Tampere	.027	.082	.645	.623
Rest of Tampere Region	.013	.068	.889	.464
Jyväkylä	.015	.081	.474	.314
Rest of Central Finland	.004	.069	.237	.073
Oulu	.027	.069	.468	.433
Rest of Oulu Region	.004	.059	.589	.152

---

[5] The coefficient estimates are based on AR(1) models with constants.

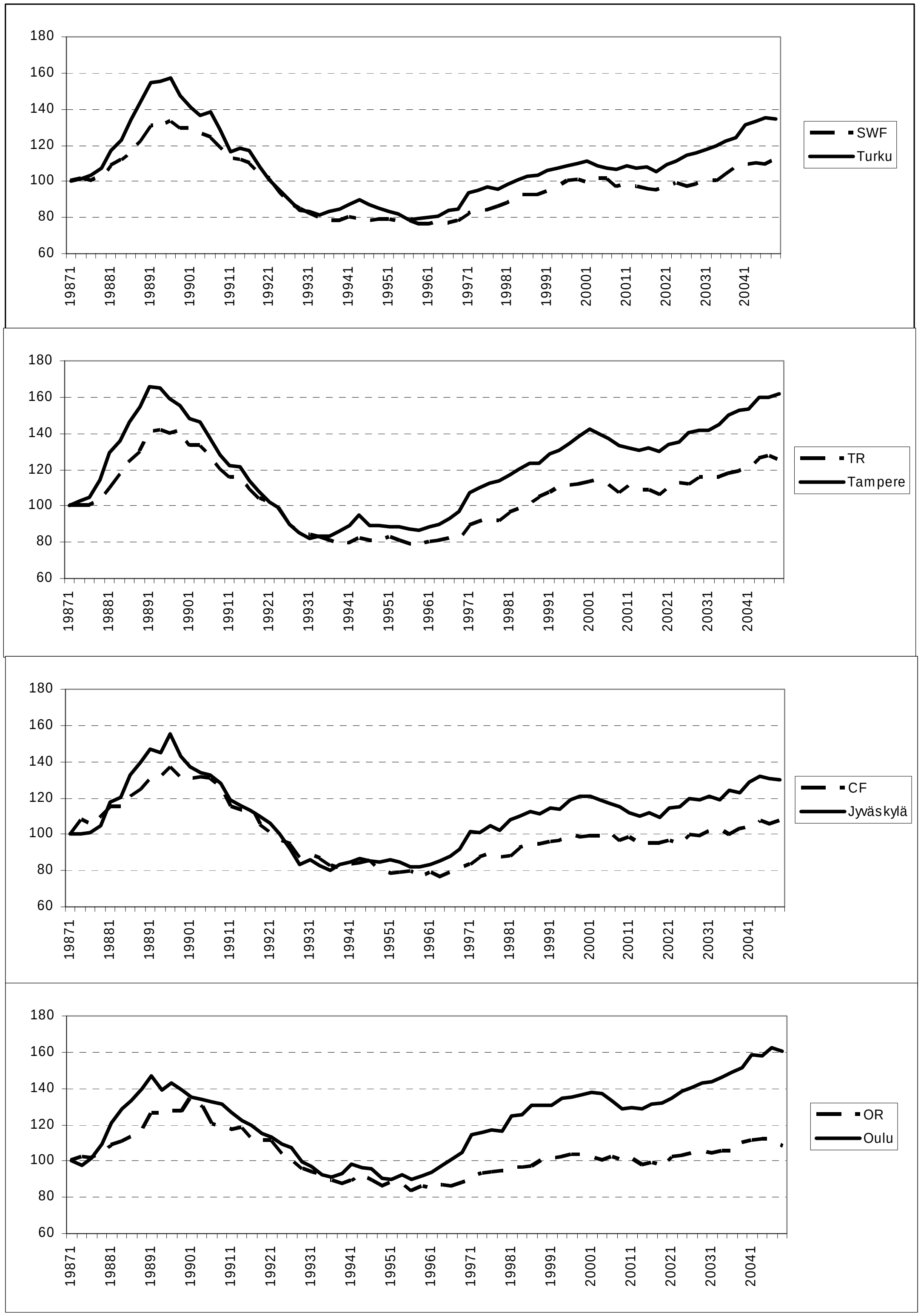

Figure 2 **The real housing price indices for the provincial centres and surrounding provinces**

According to augmented Dickey-Fuller (ADF) tests all the price indices are non-stationary but for all the differenced series non-stationarity can be rejected.[6] The finding that housing prices are I(1) is in accordance with a number of studies[7] and the results are not sensitive to the number of lags included in the ADF-tests[8]. The unit root test results are reported in Table A2 in the Appendix.

The correlation coefficients between the housing price movements in the centre, the OHMA, the Satellites, the OGC and the ROF are reported in **Table 2** using both quarterly and rolling, i.e. overlapping, annual observations. The correlation coefficients of the centre of the HMA are smaller than the other correlations reported in Table 2. This, too, is probably mainly due to the inflexible supply in the heart of the HMA. All the correlation figures grow as the observation period is lengthened from one to four quarters. This also holds for all the correlations between the regional centres and surrounding provinces. The quarterly and annual correlations are .74 and .92 between Turku and SWF, .83 and .94 between Tampere and TR, .60 and .91 between Jyväskylä and CF, and .48 and .81 between Oulu and OR. All the coefficients are large and statistically highly significant.

Table 2 Quarterly and annual correlation coefficients of real housing price changes

Quarterly	Centre of the HMA	Other parts of the HMA	Satellites	Other growth centres	Rest of Finland
Centre of the HMA	1				
Other parts of the HMA	.86	1			
Satellites	.77	.93	1		
Other growth centres	.78	.93	.91	1	
Rest of Finland	.77	.92	.94	.95	1
Annual					
Centre of the HMA	1				
Other parts of the HMA	.96	1			
Satellites	.93	.97	1		
Other growth centres	.91	.97	.98	1	
Rest of Finland	.89	.94	.98	.98	1

---

[6] The low power of various Dickey-Fuller tests is well known. However, there is no reason to use more powerful procedures to examine the existence of unit roots in this study. Firstly, the power is not a problem when studying the differences because unit root can be rejected in five percent level of significance in all the differenced series. Secondly, the value of test statistics is so close to zero in all the level series and actually even above zero in some cases that the power problem of the ADF test is very unlikely to have caused the acceptance of a false null of a unit root in any of the series. Thirdly, the results are expected and consistent with results in many other studies.

[7] Studies of e.g. Suoniemi (1990), Kosonen (1997), Barot and Takala (1998) and Oikarinen and Asposalo (2004) imply that housing prices in Finland are I(1).

[8] The number of lags in the ADF tests are decided based on Hall's general to specific method. When testing stationarity of the levels the need for deterministic regressors in the ADF tests is decided based on the ϕ_1, ϕ_2, and ϕ_3 statistics provided by Dickey and Fuller (1981). According to the graphs and theory it is obvious that deterministic regressors are not needed when testing the stationarity of the differences. No trend was needed in any of the ADF regressions. Furthermore, drift was not found necessary in any of the tests.

The growing correlations suggest that there are dynamic interdependences between the variables. Indeed, studying the cross-autocorrelations exhibited in **Table 3** reveals that strong dynamic relations between the areas exist. Even the fourth-order cross-autocorrelation figures are considerable. This implies informational inefficiency in the housing markets. Furthermore, the positive own-autocorrelations indicate mean-aversion in housing prices. At longer lags, however, own-autocorrelations as well as cross-autocorrelations are negative implying slight mean-reversion in housing prices. The figures turn negative somewhere between six and ten lags depending on the case. The negative own- and cross-autocorrelations are much smaller in size than the positive figures at shorter lags, though. These findings are similar to e.g. Case and Shiller (1990) regarding the US housing markets.

The cross-autocorrelations between capitals and surrounding provinces also indicate clearly that, expectedly, housing price movements in the capitals lead housing price changes in the peripheral areas.

Table 3 Cross-autocorrelations of quarterly housing price changes at one and four-quarter lags

t-1	Centre of the HMA (lagged)	Other parts of the HMA (lagged)	Satellites (lagged)	Other growth centres (lagged)	Rest of Finland (lagged)
Centre of the HMA	.45	.59	.60	.51	.53
Other parts of the HMA	.61	.72	.68	.66	.63
Satellites	.65	.77	.72	.74	.72
Other growth centres	.56	.70	.68	.67	.66
Rest of Finland	.62	.75	.77	.76	.74
t-4					
Centre of the HMA	.34	.34	.30	.32	.28
Other parts of the HMA	.29	.35	.28	.30	.26
Satellites	.33	.45	.44	.40	.36
Other growth centres	.33	.41	.34	.39	.33
Rest of Finland	.40	.51	.46	.47	.44

t-1	City (lagged)	Region (lagged)	**t-1**	City (lagged)	Region (lagged)
Turku	.54	.56	Jyväskylä	.31	.25
Rest of SW Finland	.63	.56	Rest of Central Finland	.38	.07
Tampere	.62	.45	Oulu	.43	.28
Rest of Tampere Region	.62	.46	Rest of Oulu Region	.40	.15
t-4			**t-4**		
Turku	.34	.21	Jyväskylä	.32	.27
Rest of SW Finland	.45	.40	Rest of Central Finland	.34	.36
Tampere	.42	.28	Oulu	.19	.11
Rest of Tampere Region	.52	.40	Rest of Oulu Region	.42	.34

5 METHODOLOGY

In the next section the dynamic interdependences between housing prices in different areas are examined econometrically. First, the existence of a cointegrating relationships between central and surrounding areas are tested employing pairwise Johansen tests. Cointegration is tested and vector-error correction model (VECM) is estimated in the case cointegrating relationship is found due to the fact that important information concerning long-run dynamics is lost if only differenced variables are used in the analysis. Lack of cointegration implies that the dynamics are only short-run in nature. Cointegrating relationship, instead, indicates that also long-run interdependences exist. In the Johansen tests two possible vector error-correction models (VECM) are considered:

$$\text{Model 1: } \Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \alpha\beta' X_{t-1} + \varepsilon_t \qquad (1)$$

$$\text{Model 2: } \Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \alpha(\beta', \beta_1)(X'_{t-1}, t)' + \varepsilon_t \qquad (2),$$

where ΔX_t is $X_t - X_{t-1}$, X_t is a vector of the housing price index values in different areas in period t, μ is a vector of drift terms, Γ_i is a vector of coefficients for the lagged differences of the endogenous variables at lag i, k is the maximum lag, i.e. the number of lags included in the corresponding vector autoregressive (VAR) model, α is a vector of the speed of adjustment parameters of the endogenous variables, β' and (β', β_1) form the cointegrating vector and ε is a vector of white noise error terms.

The difference between the models is that in Model 2 a deterministic time trend (t) is included in the cointegration space, i.e. in the long-run equilibrium relationship. Hence, Model 2 takes into account the possibility that the price indices are cointegrated but one of the indices grows faster than the other. Only models with unrestricted constant are considered because *a priori* assumption for both the Helsinki centre and the OHMA indices as well as for the indices for the regional capitals is that they exhibit growing trend. Where both models seem to be valid options in pairwise tests, the selection between the models is made based on the Schwartz Bayesian information criteria (SBC). Maximum lag is selected based on a number of statistics. These include three different information criteria, Akaike (AIC), Schwartz Bayesian (SBC) and Hannan-Quinn (HQ) together with two tests to check for autocorrelation of the residuals, LM(1) test and LM(4) test. The maximum lag is set so that the information criteria are as small as possible and the residuals in the VECM do not exhibit significant serial correlation. Furthermore, since some of the series seem to exhibit seasonal variation, the need for seasonal dummies is detected in all the tests in which one of these series is included. The inclusion or exclusion of seasonal dummies is decided based on HQ and SBC. Finally, the selection of the number of cointegrating vectors in a particular model is done by comparing the Trace and λ-max statistics with the Osterwald-Lenum (1992) tables. The Trace and λ-max statistics are not reported for the case where the number of cointegrating vectors (r) equals the number of dimensions in the model (p) because it is straightforwardly assumed that all the indices are non-stationary.

After the pairwise tests, the number of cointegrating vectors in a system consisting of four different markets is analysed. In this case the selection between Models 1 and 2 is made jointly with the determination of the number of cointegrating vectors utilising the so-called Pantula principle suggested by Johansen (1992).

In the case where one or more variables are restricted to be weakly exogenous so that they do not adjust to the long-run equilibrium, the methodology and asymptotic tables presented by Harbo et al. (1998) are applied. Then the number of cointegrating relationships in the partial model, i.e. in a model including weakly exogenous variables, is tested based on the following VECM:

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \gamma_1 \Delta Z_{t-1} + \ldots + \gamma_{k-1} \Delta Z_{t-k+1} + \alpha(\beta_X', \beta_1)(X'_{t-1}, t)' + \alpha\beta_Z{}' Z_{t-1} + \varepsilon_t \quad (3),$$

where Z_t is a vector of the weakly exogenous variables in period t and $\alpha(\beta_X', \beta_1)(X'_{t-1}, t)' + \alpha\beta_Z{}' Z_{t-1}$ forms the long-run equilibrium relationship. In the text VECM with no weakly exogenous variables is called full-system model and partial model refers to a VECM, which includes weakly exogenous variables.

In some cointegration tests the presence of a structural break seems a valid possibility. In these cases the existence of cointegrating relationship is further studied following the methodology proposed by Johansen et al. (2000) for cointegration analysis in the presence of break at known points of time. The possible break divides the whole sample period to two sub-samples. The parameters of the stochastic components are the same for both sub-samples, while the deterministic variables may change between the sub-samples. The relevant asymptotic distributions in tests containing structural break depend on the number of non-stationary relations, the location of the break and the trend specification. Hence, the quantiles have to be computed separately for each case. The quantiles can be computed based on the response surface tables reported in Johansen et al.

After being tested for cointegration time series models examining the dynamics between regions are estimated. In the cases where the hypothesis of no-cointegration is accepted, a VAR-model is estimated to study the dynamics. Taking into consideration the sluggish adjustment of housing markets at least four lags are included in each VAR-model. More lags are included if suggested by SBC or the LM(1) and LM(4) tests for residual autocorrelation.[9] The direction of the possible Granger causality is tested by a standard F-test. If it is seen worthwhile, restrictions are made to the right-hand sides. These near-VARs are then estimated by seemingly unrelated regressions (SUR) to improve the efficiency of the estimates. The lags of the dependent variable are not excluded from any of the equations. This is because it is assumed that the lags of the dependent variable have some forecasting power even if the formal F-test would allow for exclusion. If cointegration is found, instead, VECM is estimated. In VECM weak exogeneity is tested by the Likelihood Ratio test, and Granger non-causality tests are computed based on Mosconi and Giannini (1992). Finally, based on the estimated VEC- and VAR-models, impulse response analysis is conducted to study the existence of notable lead-lag relations.

It is of importance to understand that a finding that x Granger causes y does not necessarily imply that housing price movements in x cause housing price changes in y. It merely means that current and historical observations of x are statistically significant in predicting future value of y.

---

[9] The robustness of the results with respect to the selection of lag length was also studied by trying different lag lengths in each VAR-model. In all the cases the outcomes concerning Granger causalities are robust. In each case only the “best” model is reported in the text.

In addition, it has to be noted that many of the parameter estimates in the models reported are not significant in the commonly used significance levels. The goal is to find the important interrelationships between the variables and not the significant parameters. Furthermore, the relatively small number of degrees of freedom together with multicollinearity of the explanatory variables is likely to lead to higher p-values.

6 RESULTS OF THE ECONOMETRIC ANALYSIS

It has been shown above that the data implies strong dynamic interdependences between housing price movements in different regions. In this section, the dynamic relations are further examined by testing for cointegration and Granger causalities between different markets. Short- and long-term interdependences between the centre of the HMA and the OHMA are studied first. Then the hypothesis that housing price movements in the HMA lead price changes in the other parts of Finland is evaluated, after which lead-lag relations between some regional centres and provinces surrounding them are investigated. Finally, based on the estimated models impulse response functions are plotted.

6.1 Dynamic interrelations between the centre and the other parts of the HMA

Johansen test implies that there have been only short-run dynamics between ΔCentre and ΔOHMA. Maximum lag in the analysis is two since both HQ and SBC recommend two lags and the hypothesis of no autocorrelation in the residuals is accepted. Both HQ and SBC select models with no seasonal dummies. Furthermore, SBC selects Model 1. The Trace and λ-max statistics are as small as 5.6 and 3.7, respectively. The corresponding 95 percent quantiles are 15.4 and 14.1.

Visual inspection of the indices for the centre and the OHMA (see **Figure 1**) suggests that the acceptance of the null in the Johansen test might be due to a structural break in 1993. That is the time when the economy gradually started to recover from the recession. With the recovery net migration to the HMA more than doubled from 1992 to 1993, which might have caused a structural change. Thus, the existence of long-run equilibrium relationship between the two areas is further examined by allowing for a structural change in the VECM. The test involves an inclusion of a dummy variable, which is 0 until the end of 1992 and has got a value of 1 in 93/1, 2 in 93/2 etc. in the long-run equilibrium relationship and its first difference, i.e. 1, in the short-run model.[10] The Trace statistics value 19.3 suggests that the series are not cointegrated even allowing for a structural break.[11]

According to a sixth-order VAR it is apparent that ΔCentre does not Granger cause ΔOHMA. Thus, the evidence is clear against the assumption that housing price movements in the centre lead housing price changes in the OHMA. Nevertheless, there still seems to be substantial interdependence between the areas — ΔOHMA Granger causes ΔCentre. Price level has grown much faster in the centre, however. It is likely that the faster house price increase in the centre is due to the rapid population growth in the HMA. Because the

---

[10] This corresponds to the model $H_l(r)$ in Johansen et al. (2000).

[11] The 90 percent quantile is 32.5.

supply is more inflexible in the centre even in the long run, the growth of the HMA has raised price level in the centre more than in the areas with more flexible supply.

The leading role of ΔOHMA has probably got much to do with the growth pattern of employment opportunities in the HMA. During the sample period the number of jobs located in the OHMA has grown substantially faster than the number of employment opportunities in the centre. Therefore, based on the logic concerning housing price movements inside a metropolitan area explained in part two, the fact that ΔOHMA has led ΔCentre is not totally unexpected. The leading role of ΔOHMA according to this view is due to the substitution effect. The finding that there is no significant feedback effect from the centre to the OHMA may be accounted for by the size difference between the centre and the suburbs. The number of flats in the OHMA is about 15 times the number of flats in the centre. Due to the substitution effect price change in the centre relative to the suburbs affects housing demand also in the suburbs. However, the increase in the demand in the suburbs is likely to be negligible because of the large size of the area. In contrast, the change of demand in the centre induced by relative price change in the surroundings is likely to be much more significant.

Because it is evident that ΔCentre does not Granger cause ΔOHMA, the lags of the Centre can be excluded from the ΔOHMA equation. Hence, a near-VAR is estimated eventually to study the dynamics between the two areas. The constants are highly insignificant and are excluded from the model. The results are presented in Table 4.

6.2 Dynamic interrelations between the HMA and the other parts of Finland

It would be surprising to get any other results than that ΔHMA leads ΔSatellites. Although the maximum lag should be set to two in the Johansen test according to HQ and SBC, it is set to six to extract significant autocorrelation in the residuals. SBC selects Model 2 to be tested. The Trace and λ-max statistics of 33.7 and 27.1, respectively, imply the existence of a cointegrating relationship between the variables.[12] It has to be noted that the small number of degrees of freedom in the model may create size distortions, i.e. finding cointegration even though long-run equilibrium relationship does not really exist. The disequilibrium from the cointegration relation seems to be stationary reinforcing the inference of the existence of cointegration, however. In Figure A1 in the Appendix the lower graph pictures the actual disequilibrium and should be stationary in case the variables are cointegrated.

The results of the full-system VECM are as expected. ΔHMA Granger causes ΔSatellites but not vice versa. Furthermore, housing price level in the Satellites is the one that adjusts to deviation from the long-run equilibrium. Also this is anticipated. Price level in the HMA does not react to disequilibrium from the long-run relationship statistically significantly. The LR test indicates that the HMA can be restricted to be weakly exogenous (p-value = .77). Also the Johansen test for the partial model indicates the existence of cointegration. The Trace test value is 27.0 with 15.2 being the 95 percent quantile in the Harbo et al. (1998) tables.

---

[12] The one percent quantile is 30.5 in the Trace test and 23.7 in the λ-max test.

Table 4 **Summary of the near-VAR-Model including the centre of the HMA and the other parts of the HMA**[13]

	ΔOHMA		ΔCENTRE	
ΔOHMA(1)	.748**	(6.15)	.829**	(3.73)
ΔOHMA(2)	.044	(.30)	.242	(1.00)
ΔOHMA(3)	-.227	(-1.76)	-.663**	(-3.02)
ΔOHMA(4)	.376**	(2.90)	.454*	(2.02)
ΔOHMA(5)	-.152	(-1.12)	.281	(1.21)
ΔOHMA(6)	-.122	(-1.10)	.-.361	(-1.80)
ΔCENTRE(1)			-.140	(-1.13)
ΔCENTRE(2)			-.000	(-.00)
ΔCENTRE(3)			.083	(.71)
ΔCENTRE(4)			.151	(1.31)
ΔCENTRE(5)			-.229*	(-1.98)
ΔCENTRE(6)			-.016	(-.14)
R^2	.59		.49	
Residual analysis (p-values)				
Jarque-Bera	.39		.53	
LM(1)	.31		.10	
LM(4)	.30		.42	
Granger causality based on the sixth-order VAR (p-values, explanatory variable on the left)				
ΔOHMA	.01		.01	
ΔCENTRE	.54		.57	

The eventual VECM is summarized in **Table 5**. The speed of adjustment parameter of the Satellites is as high as .66 implying relatively fast adjustment to the long-term equilibium. The cointegrating relationship between these two housing markets can be explained by the fact that dwellings in the two areas are relatively close substitutes for one another. For example, a great number of people commute from the Satellites to the HMA. In this sense it is surprising that the centre and the other parts of the HMA do not seem to be cointegrated. Perhaps there are, after all, a substantial number of dwellers in the centre who do not consider housing in the OHMA as a close substitute[14]. The fact that price level in the HMA does not react significantly to deviations from the long-run relationship with the Satellites may be partly due to the much bigger size of the HMA housing market.

---

[13] * and ** denote for five and one percent level of significance, respectively. t-values are reported in the parenthesis.

[14] This could also, at least partly, explain the fact that a feedback effect from the centre to the OHMA does not seem to exist.

Table 5 Summary of the VECM including the HMA and the Satellites

	ΔHMA		ΔSatellites	
Constant	.000	(0.08)	-.124**	(-3.00)
ΔHMA(1)	.677*	(2.61)	.300	(1.38)
ΔHMA(2)	.050	(.18)	-.387	(1.70)
ΔHMA(3)	-.440	(-1.82)	-.510*	(-2.52)
ΔHMA(4)	.515*	(2.28)	-.167	(-.88)
ΔHMA(5)	-.148	(-.62)	-.306	(-1.53)
ΔSatellites(1)	.100	(.38)	.329	(1.49)
ΔSatellites(2)	.012	(.05)	.372	(1.85)
ΔSatellites(3)	.238	(1.02)	.318	(1.63)
ΔSatellites(4)	-.208	(-.96)	.154	(.84)
ΔSatellites(5)	-.092	(-.44)	-.096	(-.55)
β[15]			.663**	(2.96)
R^2	.60		.72	
All the values reported below are p-values				
Jarque-bera	.28		.51	
LM(1) (system)	.12			
LM(4) (system)	.86			
Granger non-causality	.00		.88	

Plotting the graph of the series (see the **Figure 1**) shows that only Model 1 is to be considered in the Johansen test for the HMA and the OGC. All the information criteria suggest the selection of two for the maximum lag. Nevertheless, the LM(4) test rejects the hypothesis of no autocorrelation if the maximum lag is less than three. The Trace statistics are not sensitive to the lag length in this case and reject the hypothesis of no-cointegration with both lag specifications[16]. The λ-max statistics, on the other hand, accept no cointegration in the two-lag case but rejects the null in the ten percent significance level in the three-lag case.

In the VECM with the maximum lag either two or three the speed of adjustment parameter of ΔHMA has got the wrong sign. Also the parameter estimates for the constants seem implausible. Since weak exogeneity can be accepted for the HMA at the usual level of significance, a model with HMA as a weakly exogenous variable is also estimated. Then, however, the evidence in support of cointegration is weak. The Trace statistics value is 9.9 and the 90 percent quantile is 13.2.

Because of the problems in the VECM, VAR-model is estimated to study the causality between the variables. It is logical that the HMA is pairwise cointegrated with the Satellites but not with regions much farther away from it. This is because housing in regions such as

---

[15] β = HMA(t-1) - .947*Satellites(t-1) - .003*(t-1)

[16] The Trace statistics are 16.4 and 16.8 in the two and three lag case, respectively. The corresponding λ-values are 12.0 and 13.1. The five percent quantiles are 15.4 and 14.1 in the Trace test and λ-max test, respectively.

the OGC and the ROF cannot be regarded as close substitutes for housing in the HMA. For the VAR-model AIC and SBC propose five and one lags, respectively. The most parsimonious model that both LM(1) and LM(4) accept includes five lags. As expected, the VAR analysis shows evidence of housing price changes in the OGC following the movements in the HMA[17] and there is no feedback from the OGC to the HMA. A near-VAR is eventually estimated to study the dynamics between the regions. The model is presented in Table 6.

Table 6 Summary of the near-VAR-model including the HMA and the other growth centres

	ΔHMA		ΔOGC	
ΔHMA(1)	.740**	(6.37)	.352**	(2.96)
ΔHMA(2)	.085	(0.66)	.168	(1.30)
ΔHMA(3)	-.257*	(-2.03)	-.224	(-1.74)
ΔHMA(4)	.392**	(3.04)	.277*	(2.14)
ΔHMA(5)	-.239*	(-2.20)	-.201	(-1.68)
ΔOGC(1)			.160	(1.31)
ΔOGC(2)			.021	(.17)
ΔOGC(3)			.072	(.60)
ΔOGC(4)			.121	(1.05)
ΔOGC(5)			-.105	(-.92)
R^2	.58		.62	
Residual analysis (p-values)				
Jarque-Bera	.23		.02	
LM(1)	.10		.31	
LM(4)	.15		.25	
Granger causality based on the fifth-order VAR (p-values, explanatory variable on the left)				
ΔHMA	.01		.05	
ΔOGC	.73		.55	

For the Johansen test between the HMA and the ROF Model 2 is preferred by SBC. Maximum lag of two is suggested by HQ and SBC and is acceptable also according to the LM tests. The hypothesis of no-cointegration is accepted by the Trace and λ-max statistics[18]. Hence, a fifth-order VAR with no constant is estimated. The relationship between the HMA and the ROF is in accordance with the theory — price changes in the HMA Granger cause changes in the ROF but not the other way around. Thus, again there does not seem to be feedback from the surrounding regions to the HMA and a near-VAR is also estimated to study the dynamics between ΔHMA and ΔROF. The model is summarized in **Table 7.**

---

[17] The ΔHMA also Granger causes housing price movements in all the four cities included in the OGC separately.

[18] The Trace and λ-max statistics are 20.7 and 14.9, respectively. The corresponding five percent quantiles are 25.3 and 19.0.

Table 7 **Summary of the near-VAR-model including the HMA and the rest of Finland**

	ΔHMA		ΔROF	
ΔHMA(1)	.740**	(6.37)	.295**	(3.12)
ΔHMA(2)	.085	(0.66)	.025	(0.25)
ΔHMA(3)	-.257*	(-2.03)	-.296**	(-3.00)
ΔHMA(4)	.392**	(3.04)	.294**	(2.92)
ΔHMA(5)	-.239*	(-2.20)	-.061	(-.67)
ΔROF(1)			.221	(1.82)
ΔROF(2)			.198	(1.66)
ΔROF(3)			.346**	(3.08)
ΔROF(4)			-.115	(-1.01)
ΔROF(5)			-.207*	(-1.96)
R^2	.58		.70	
Residual analysis (p-values)				
Jarque-Bera	.23		.85	
LM(1)	.10		.23	
LM(4)	.15		.16	
Granger causality based on the fifth-order VAR (p-values, explanatory variable on the left)				
ΔHMA	.01		.03	
ΔROF	.97		.15	

Between the three regions outside the HMA there does not appear to be either cointegrating relations or short-run causalities. The predictive power of the GDP growth on housing price movements in different areas was also briefly tested. It is interesting that GDP growth does not seem to Granger cause housing price changes in any of the areas. On the contrary, housing price movements in all the regions Granger cause GDP growth. It would require more detailed analysis to study this phenomenon in depth. In any case, the relationship between housing price movements and GDP growth implies that the leading role of the HMA is probably not due to different timing of business cycles in different regions but is a consequence of informational factors.

Next, the interdependences between the prices in different areas are studied by including four areas, the HMA, the Satellites, the OGC and the ROF, in the analysis simultaneously. The purpose of this analysis is to examine if there exist other cointegrating relations between the regions than the one between the HMA and the Satellites found above.

In the four-variable system, the model with the lowest possible SBC and HQ where no-autocorrelation cannot be rejected includes six lags in the VAR specification. The Trace and λ-max statistics can be seen in **Table 8**. The Pantula principle selects one cointegrating vector and Model 1 in the five percent level of significance. The λ-max statistics confirms the selection of one cointegrating relationship when Model 1 is concerned.

The full-system analysis suggests that the HMA, the OGC and the ROF are weakly exogenous. Only the alfas of the OGC and the ROF can be restricted to equal zero simultaneously, however. The p-value for restricting $\alpha(OGC) = \alpha(ROF) = 0$ is .30 in the LR test. This restriction also removes the problem that the alfa of the ROF has got the wrong sign.

The Trace statistics of the partial model, i.e. the model in which the OGC and the ROF are weakly exogenous, are 61.3 (p-r = 2) and 10.9 (p-r = 1) and corresponding 95 percent quantiles are 35.5 and 17.9, respectively. Thus, also the partial model indicates that r = 1. The deterministic trend in the cointegration space cannot be excluded from the partial model according to the LR test. These results, especially after noting that in the partial model both the OGC and the ROF can be separately excluded from the long-run equilibrium relationship[19], suggest that there exists only one cointegrating relationship between the variables, which is the relationship between the HMA and the Satellites already found above. The eventual model is reported in the Appendix. The conclusion that the other areas do not possess predictive power with respect to ΔHMA is strengthened by the Granger non-causality test. The p-value for the hypothesis that housing price changes in the other areas together do not Granger cause ΔHMA is .91.

Table 8 Trace and λ-max statistics in the full-system model consisting of four areas[20]

	Trace		λ-max	
p-r	Model 1	Model 2	Model 1	Model 2
4	67.7** (47.2)	100.5** (63.0)	39.1** (27.1)	53.9** (31.5)
3	28.6 (29.7)	46.7* (42.4)	18.5 (21.0)	26.1* (25.5)
2	10.1 (15.4)	20.6 (25.3)	10.0 (14.1)	10.8 (19.0)

6.3 Dynamic interrelations between provincial capitals and surrounding provinces

As expected, housing price movements in all the regional centres Granger cause housing price changes in surrounding provinces. Two of the regional capitals seem to have a long-term equilibrium relationship with the surrounding province. Both of these cointegrating relations require a deterministic trend term. The Trace and λ-max test values are 26.3 and 23.4 in the model including Turku and SWF, and 33.2 and 29.8 in the model with Tampere and TR. The model including Tampere and TR requires also seasonal dummies. Expectedly, only the surrounding province adjusts to deviations from the long-run equilibrium between Turku and SWF. Also the partial model, i.e. model where Turku is weakly exogenous, indicates the existence of a cointegrating vector. The Trace test value is 21.9 with 15.2 being the 95 percent quantile. In contrast, Tampere does respond to disequilibrium from the equilibrium relationship with TR. Between Jyväskylä and CF, and Oulu and OR there seem to be only short-run dynamics. The eventual models estimated for the purposes of the impulse response analysis are summarized in the Appendix. In both of the cointegrated cases the analysis also shows some evidence of feedback effect from periphery to the centre – the Granger non-causality can be rejected at the ten percent level of significance. In the cases with only short-run dynamics feedback does not exist.

---

[19] P-values in the LR test are .54 and .62 for the OGC and the ROF, respectively.

[20] Five percent quantiles in the parenthesis.

The finding that housing prices in Turku and Tampere are cointegrated with the housing price level in the surrounding province but Oulu and the rest of Oulu region do not have a long-run equilibrium relation is sensible. SWF and TR are geographically relatively small areas, whereas OR is more than twice as large in area as SWF or TR. Jyväskylä, instead, may be located too close to the bigger city of Tampere to form a tight long-run relation with the surrounding areas. This thought is supported by the fact that housing price level in CF is actually cointegrated with housing prices in Tampere.

6.4 Impulse response analysis

The analysis above shows that future housing price movements in the centre of the HMA can be better predicted by housing price changes in the other parts of the area than by changes in the centre itself, i.e. ΔOHMA leads Δcentre. Similarly, one can make more accurate predictions for capital returns in the Satellites, in the OGC and in the ROF by using capital returns in the HMA in the model instead of the price movements in the regions themselves. Furthermore, the results imply that housing price movements in regional centres lead housing price changes in the surrounding provinces.

In order to evaluate the interrelations between the areas further, impulse response functions are plotted based on the pairwise models reported above. In the case of the HMA and the other Finnish regions pairwise models are used instead of the model including all the four variables due to the relatively short sample period and thus the small number of degrees of freedom. It is assumed that the more parsimonious pairwise models give more accurate parameter estimates and are therefore better to use. In any case, the impulse responses based on the model including all the four areas do not differ notably from the impulses derived from the pairwise model, which can be seen by comparing **Figure 5** with Figure A2 in the Appendix.

The impulse response functions exhibited in Figures 3 and 5 can be interpreted as follows. Effects of a shock in Δ(O)HMA show how much higher capital returns (than was predicted prior to the shock) are predicted by the relevant model due to a positive shock[21] in capital returns in the (O)HMA. Similar interpretation applies also to Figures 7 through 10. The accumulated effects pictured in Figures 4 and 6, in turn, exhibit the cumulative change in the predicted capital returns due to a shock in Δ(O)HMA. Because the estimated models do not necessarily imply that Δ(O)HMA causes housing price changes in different regions, I speak about predictions or expectations in this connection rather than say that a shock in Δ(O)HMA causes or leads to the presented impulse responses.

Figure 3 exhibits impulse responses of ΔOHMA and Δcentre to a shock in ΔOHMA. The numbers in the horizontal axis of the Figure refer to the duration from the shock in quarters. The impulses turn negative after about one and a half years and eventually die out. Even though ΔOHMA Granger causes Δcentre, the Figure does not show evidence supporting the existence of a noteworthy lead-lag relation. Furthermore, although housing prices in the OHMA and the Centre are not cointegrated, it seems that the price movements follow each other closely after a shock in ΔOHMA. This can also be seen well in **Figure 4**.

---

[21] In this case the shock is equal to the standard error of the forecast for Δ(O)HMA in extent.

The fact that there does not appear to be lead-lag relation according to the impulse responses does not probably mean that there is no such relation. According to Granger (1969) "*in many economic situations an apparent instantaneous causality would disappear if the economic variables were recorded at more frequent time intervals*". If monthly or even weekly data could be used instead of quarterly data, clear lead-lag relation between ΔOHMA and Δcentre might be perceived.

Figure 5 indicates that a positive capital returns shock in the HMA leads to higher expected capital returns in all the four regions, the HMA, the Satellites, the OGC and the ROF, for as long as two years.[22] The accumulated effects on ΔSatellites follow those of ΔHMA closely. The accumulated effects on ΔOGC and ΔROF, in contrast, are substantially smaller. This can partly be explained by the fact that the OGC and the ROF lie farther from the HMA – they cannot be considered as close substitutes and have no long-run equilibrium relationship with the HMA. Another explanation is that the variance of housing price movements is smaller in the OGC and in the ROF than in the HMA and in the Satellites, which implies that the response of ΔOGC and ΔROF to a macro shock is likely to be smaller than the response of ΔHMA and ΔSatellites.

Although the impulse responses of ΔSatellites, ΔOGC and ΔROF peak immediately as the shock in ΔHMA occurs, the graphs imply the existence of lead-lag relation, albeit only slight, between ΔHMA and price movements in the other areas. The effect of a shock in capital returns decreases relatively fast in the HMA during the first year after the shock. In the OGC and in the ROF the immediate responses to the shock are smaller but the responses do not shrink as fast as in the HMA. Four quarters from the shock the effects on ΔOGC and ΔROF are still almost as large as the immediate effects. This indicates that the HMA housing market adjusts to the new information set (shock) somewhat faster than housing markets in the other growth centres or the rest of Finland. For example, the aggregate proportion of the immediate and first quarter responses on ΔHMA from the eventual accumulated effects is .49. The corresponding figures are .41, .40 and .35 for the ΔSatellites, ΔOGC and ΔROF, respectively.

It is likely that more frequent data could bring stronger evidence concerning the lead-lag relation between the HMA housing markets and the other regions' housing markets. The relevant information for housing price movements just diffuses so fast that quarterly data is too infrequent to prove the existence of a stronger lead-lag relationship between the HMA and the other areas.

It is expected that housing markets in the Satellites adjust somewhat faster than in the other regions because the Satellites are located next to the HMA. Furthermore, it is logical that adjustment in the OGC markets is more rapid than in the ROF. This is because economic structure of the OGC reminds the economic structure of the HMA more and the OGC are much more densely populated than the ROF – population density is likely to quicken the information diffusion. The phenomenon is also in line with some other informational factors presented in Section 3, such as the existence of informed and non-informed actors in the market.

---

[22] Naturally, the impulse responses of ΔHMA are not exactly the same based on the VECM model including the HMA and the Satellites as they are based on the other two pairwise models. The difference, nevertheless, is only slight. The impulse responses of ΔHMA presented in Figures 4 and 5 are based on the pairwise near-VAR-models exhibited in Tables 6 and 7.

The impulse responses derived from the models estimated for the regional centres and surrounding provinces presented in Figures 7 through 10 show patterns similar to Figure 5. Housing prices in the centres adjust to a shock more rapidly than in the peripheral areas. The shares of the immediate responses from the eventual accumulated responses are .31 and .16 for Turku and SWF, .39 and .22 for Tampere and TR, and .41 and .27 for Jyväskylä and CF. The relation between ΔOulu and ΔOR is an exception. The impulse responses to a shock in ΔOulu show substantially clearer evidence on a lead-lag relation than the other Figures – the impulse responses of ΔOR peak two quarters after the initial shock.

It is also noteworthy that, similarly to the autocorrelation figures discussed earlier, the impulse responses indicate mean-aversion in capital returns on housing at least up to six quarters. In other words, a positive shock now anticipates higher returns also in the relatively near future. Mean-aversion in capital returns may somewhat reduce the attractiveness of housing as a long-term investment.

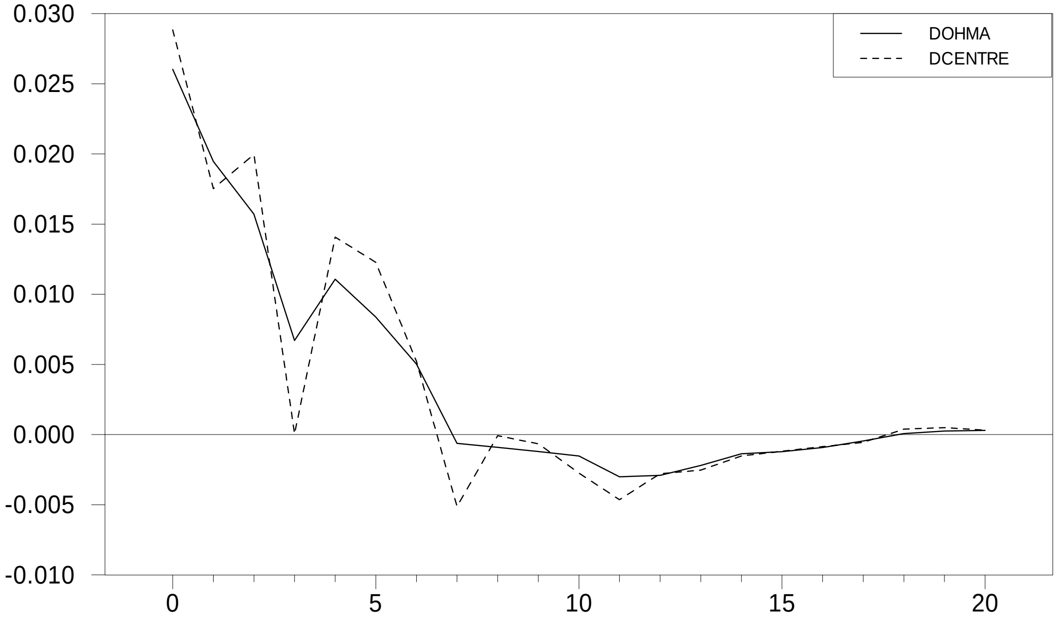

Figure 3 Impulse responses to a one standard deviation shock in ΔOHMA

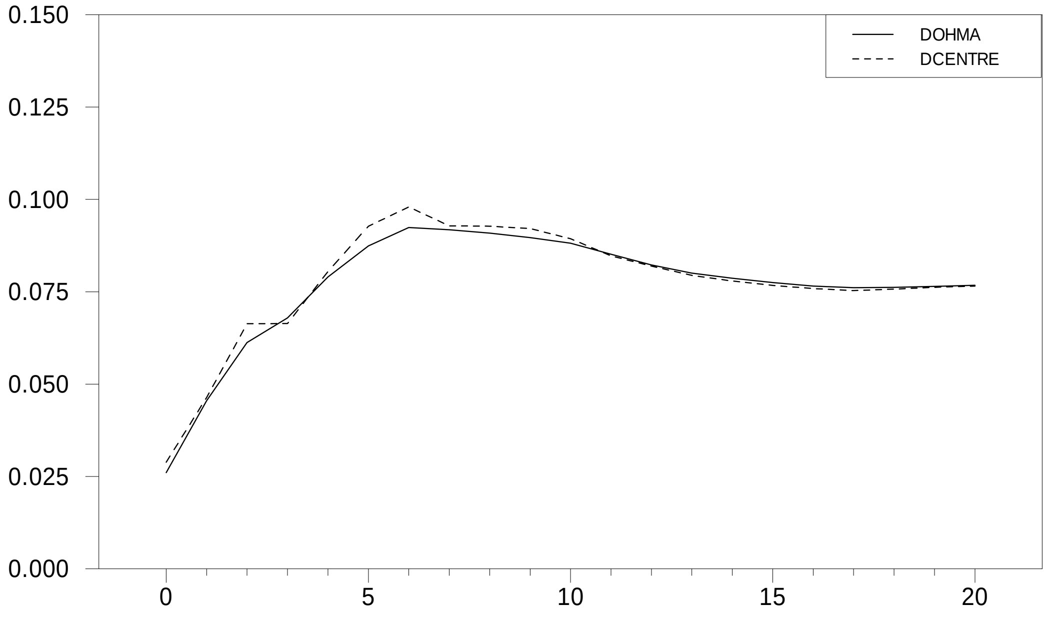

Figure 4 **Accumulated impulse responses to a one standard deviation shock in ΔOHMA**

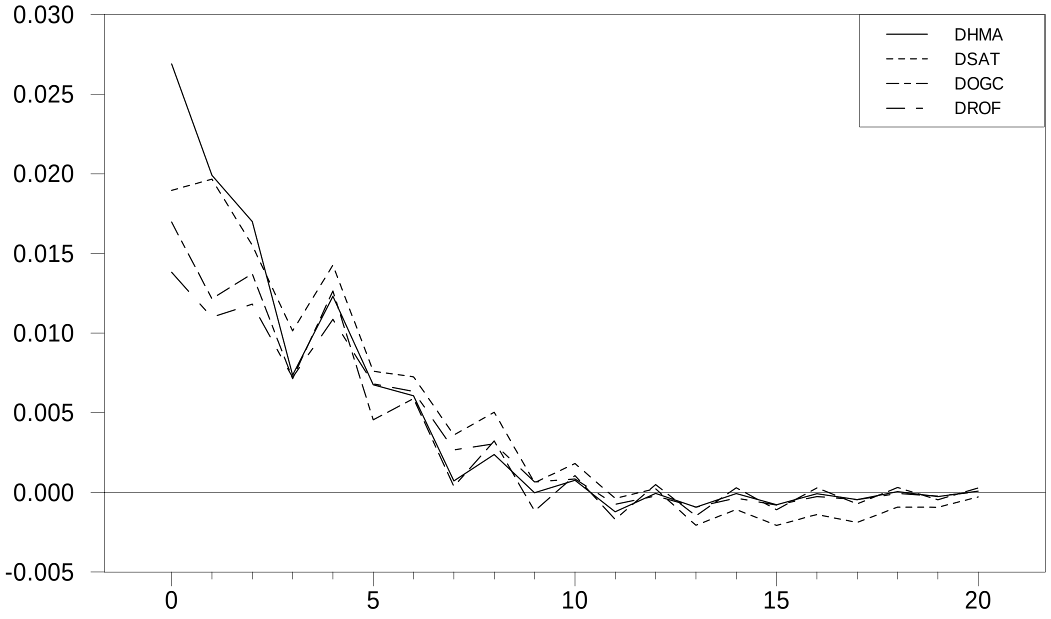

Figure 5 **Impulse responses to a one standard deviation shock in ΔHMA**

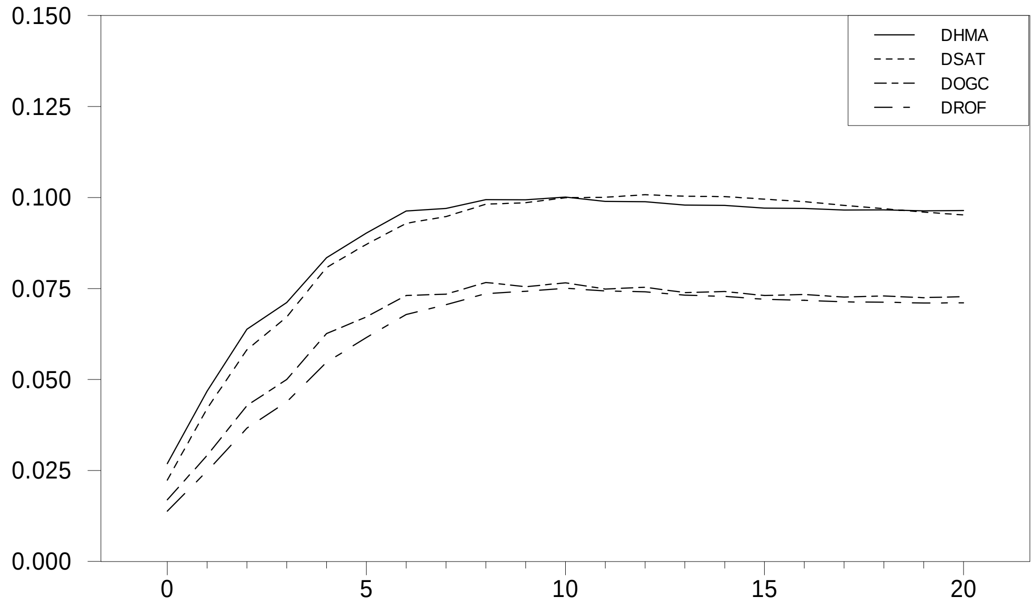

Figure 6 Accumulated impulse responses to a one standard deviation shock in ΔHMA

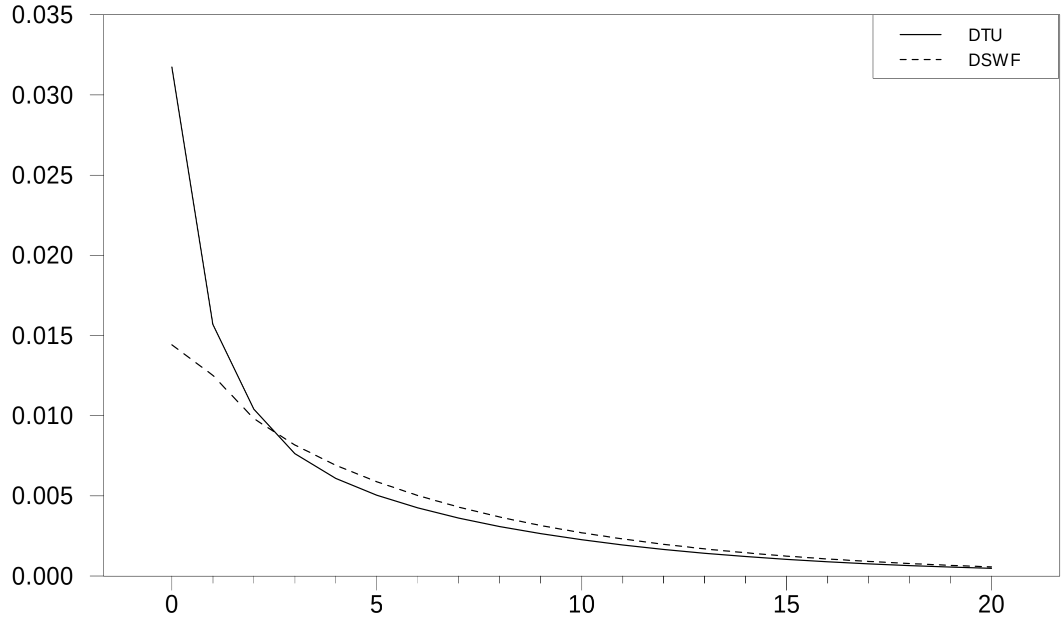

Figure 7 Impulse responses to a one standard deviation shock in ΔTurku

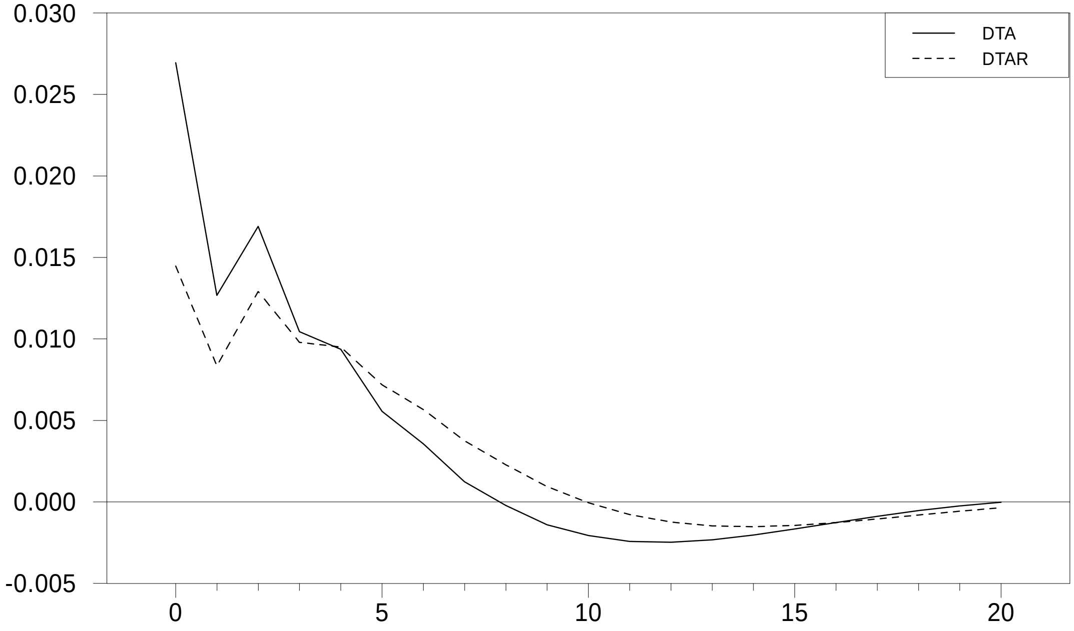

Figure 8 Impulse responses to a one standard deviation shock in ΔTampere

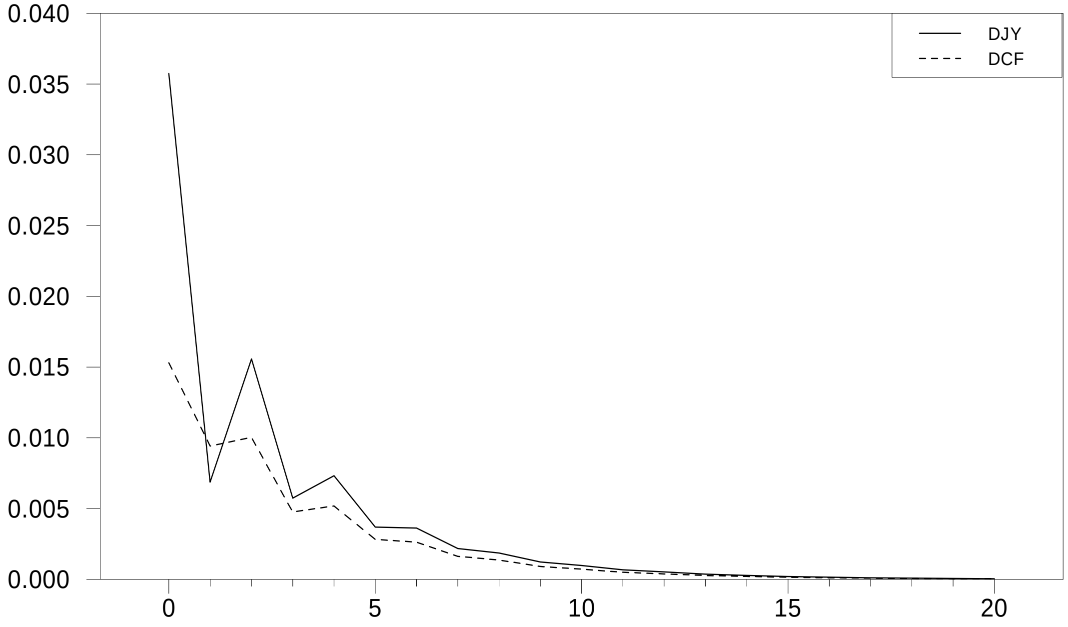

Figure 9 Impulse responses to a one standard deviation shock in ΔJyväskylä

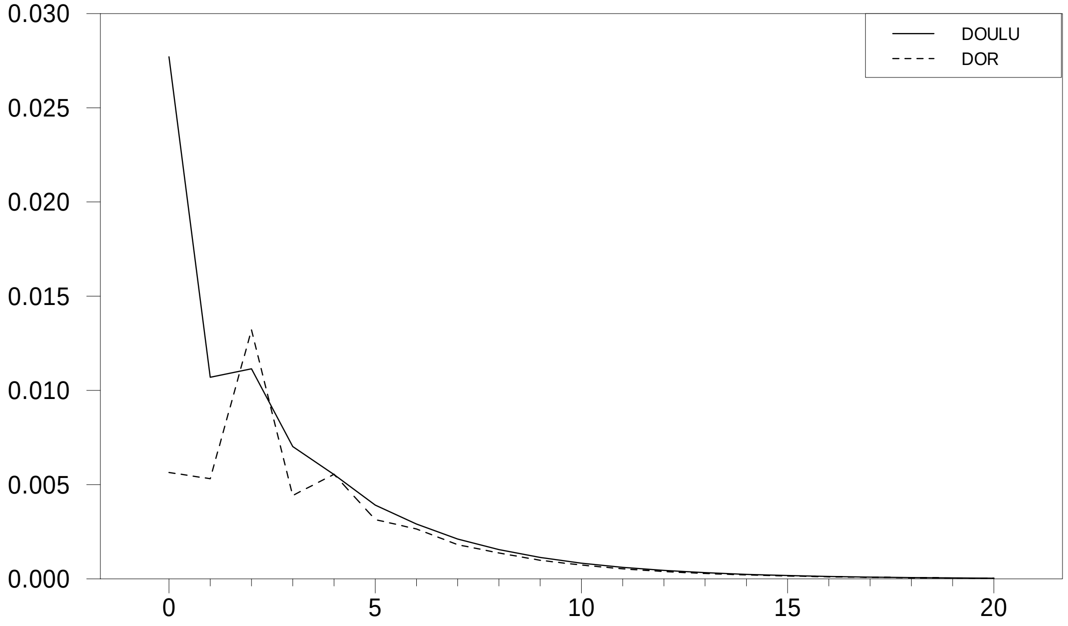

Figure 10 Impulse responses to a one standard deviation shock in ΔOulu

7 CONCLUSIONS

The purpose of the study was to examine the diffusion of housing price movements in the Finnish regional housing markets. Of particular interest were the dynamics between central and surrounding areas. Using quarterly data from 1987 to 2004 cointegration tests were conducted and vector autoregressive and vector error-correction models were estimated to study the relationships between different housing markets.

The results showed that housing price changes in the Helsinki Metropolitan Area, the main economic centre in Finland, Granger cause housing price movements in the other regions in Finland. Inside the HMA, however, housing price changes in the suburbs have Granger caused movements in the city centre. This is a good example of the fact that the dynamics between centre and surroundings may be the other way around within a geographically small metropolitan area compared with the broader economy. Between distant areas informational factors are likely to cause the leading role of the centre. Within a metropolitan area, instead, employment growth pattern and migration may have a major role.

The impulse response analysis implied that the HMA housing markets adjust to a shock more rapidly than the other markets and thus price movements in the HMA lead price changes in the other regions. Similar relation was found also between regional centres and surrounding provinces. Hence, the price movements seem to diffuse first from the HMA to the regional centres and then to the peripheral regions. This phenomenon is in line with the theory and is likely to be mostly due to informational factors. Nevertheless, the analysis indicated that the diffusion of relevant information across regions is relatively fast. Thus, quarterly data shows only slight evidence of lead-lag relationship between regional housing price movements.

The existence of strong positive interdependences between regional housing markets may strengthen cycles in the economy due to the wealth effect of housing. The dynamics between different markets are also of relevance concerning asset allocation. Because of the dynamic interrelationships, housing returns in different regions are likely to correlate extremely strongly with each other especially in the longer horizon. Hence, the use of quarterly correlations in housing portfolio analysis is misleading and may result in misdirected investment strategies. It is also evident that the use of unconditional investment opportunity sets in housing portfolio analysis is not valid because even historical price data can be used to predict future returns. In addition, the need for inclusion of up to six quarterly lags to extract significant autocorrelation in the estimated models implies informational inefficiency. Whether one can take advantage of this inefficiency to make profit is another question, however, due to the high transaction costs and low liquidity of housing.

The paper also discussed several possible reasons for the lead-lag relations between regions. The finding that housing price movements lead GDP changes implies that the relations are mainly a consequence of informational factors. The aim of the paper, however, was not to evaluate the driving factors behind the lead-lag relations in more detail. This task is left for future research.

REFERENCES

Benjamin, John D. – Chinloy, Peter – Jud, G. Donald (2004) Why Do Households Concentrate Their Wealth in Housing? *Journal of Real Estate Research*, 26 (4): 329-343.

Berg, Lennart (2002) Prices on the Second-Hand Market for Swedish Family Houses: Correlation, Causation and Determinants. *European Journal of Housing Policy* 2 (1): 1-24.

Booth, Geoffrey G. - Martikainen, Teppo – Yiuman, Tse (1996) *Long-run Price Transmission in the Different Regions of the Finnish Housing Market*. Proceeding of the University of Vaasa. Discussion Papers 190.

Case, Karl E. – Shiller, Robert J. (1990) Forecasting Prices and Excess Returns in the Housing Market. *AREUEA Journal*, 18 (3): 253-273.

Case, Karl E. – Mayer, Christopher J. (1996) Housing price dynamics within metropolitan area. *Regional Science and Urban Economics*, 26: 387-407.

Case, Karl E. – Quigley, John M. – Shiller, Robert J. (2001) *Comparing wealth effects: the stock market versus the housing market*. National Bureau of Economic Research, Working Paper 8606.

Clapp, John M. – Tirtiroglu, Dogan (1994) Positive feedback trading and diffusion of asset price changes: Evidence from housing transactions. *Journal of Economic Behavior and Organization*, 24: 337-355.

Clapp, John M. – Dolde, Walter – Tirtiroglu, Dogan (1995) Imperfect Information and Investor Inferences From Housing Price Dynamics. *Real Estate Economics*, 23 (3): 239-269.

Dickey, David – Fuller, Wayne A. (1981) Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. *Econometrica*, 49 (4): 1057-1072.

Dolde, Walter – Tirtiroglu, Dogan (1997) Temporal and Spatial Information Diffusion in Real Estate Price Changes and Variances. *Real Estate Economics*, 25 (4): 539-565.

Granger, C.W.J. (1969) Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica*, 37 (3): 424-438.

Grossman, Sanford J. – Stiglitz, Joseph E. (1976) Information and Competitive Price Systems. *The American Economic Review*, 66 (2): 246-253.

Harbo, Ingrid – Johansen, Soren – Nielsen, Bent – Rahbek, Anders (1998) Asymptotic Inference on Cointegration Rank in Partial Systems. *Journal of Business and Economic Statistics*, 16 (4): 388-399.

Hämäläinen, Kari – Böckerman, Petri (2004) Regional labour market dynamics, housing and migration. *Journal of Regional Science*, 44 (3): 543-568.

Johansen, Soren (1992) Determination of the Cointegration Rank in the Presence of a Linear Trend. *Oxford Bulletin of Economics and Statistics*, 54 (3): 383-397.

Johansen, Soren – Mosconi, Rocco – Nielsen, Bent (2000) Cointegration analysis in the presence of structural breaks in the deterministic trend. *Econometrics Journal*, 3 (): 216-249.

Kosonen, Katri (1997) *House Price Dynamics in Finland*. Labour Institute for Economic Research, Discussion Papers 137: Helsinki.

Kuosmanen, Petri (2002) *Riski ja tuotto asuntomarkkinoilla*. Doctor's Thesis. Acta Wasaensis No 107: Vaasa.

MacDonald, Ronald – Taylor, Mark P. (1993) Regional Housing Prices in Britain: Long-Run Relationships and Short-Run Dynamics. *Scottish Journal of Political Economy*, 40 (1): 43-56.

Meen, Geoffrey (1996) Spatial aggregation, spatial dependence and predictability in the UK housing market. *Housing Studies*, 11 (3): 345-372.

Mosconi, Rocco (1998) *MALCOLM. The theory and practise of cointegration analysis in RATS*. GRETA Associati: Venezia.

Mosconi, Rocco – Giannini, Carlo (1992) Non-Causality in Cointegrated Systems: Representation, Estimation and Testing. *Oxford Bulletin of Economics and Statistics*, 54 (3): 399-417.

Oikarinen, Elias – Asposalo, Henri (2004) *Housing portfolio diversification potentials in the Helsinki Metropolitan Area in the short and long horizon*. Turku School of Economics and Business Administration, Discussion Paper Series 11:2004. Turku.

Osterwald-Lenum, Michael (1992) A Note with Quantiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistics. *Oxford Bulletin of Economics and Statistics*, 54 (3): 461-472.

Pollakowski, Henry O. – Ray, Traci S. (1997) Housing Price Diffusion Patterns at Different Aggregation Levels: An Examination of Housing Market Efficiency. *Journal of Housing Research*, 8 (1): 107-124.

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

Sims, Christopher A. (1980) Macroeconomics and Reality. *Econometrica*, 48 (1): 1-48.

Smyth, Russell – Nandha, Mohan (2003) Cointegration and Causality in Australian Capital City House Prices 1986-2001. *Journal of Economic and Social Policy*, 7 (2): 35-50.

Tarbert, Heather (1998) The long-run diversification benefits available from investing across geographical regions and property type: evidence from cointegrations tests. *Economic Modelling*, 15, 49-65.

Thomas, Alun (1993) The influence of wages and house prices on British interregional migration decision. *Applied Economics*, 25: 1261-1268.

Wilson, Patric J. – Gerlach, Richard – Zurbruegg, Ralf (2003) Potential Diversification Benefits in the Presence of Unknown Structural Breaks: An Australian Case Study. *Australian Economic Papers*, 42 (4): 442-453.

APPENDIX 1 CONSTRUCTION OF INDICES

The methods of counting housing price changes in the OHMA, the OGC and the ROF are explained below.[23] The housing price indices for these areas have been counted as follows:

$ind_{i,t} = (1 + \Delta ind_{i,t}) * ind_{i,t-1}$.

$ind_{i,t}$ = value of the area i index in period t
$\Delta ind_{i,t}$ = change in the area i index from period t-1 to period t

OHMA

In the HMA index the change in the index is approximately the weighted average of the change in the centre and the change in the OHMA, where the changes have been weighted by the number of observations. Therefore, the change in the OHMA index in each quarter has been estimated according to the following formula:

$\Delta ind_{ohma,t} = (nobs_{hma,t} * \Delta ind_{hma,t} – nobs_{c,t} * \Delta ind_{c,t}) / (nobs_{hma,t} – nobs_{c,t})$.

$\Delta ind_{ohma,t}$ = change in the OHMA index from period t-1 to period t
$nobs_{hma,t}$ = number of observations in the HMA during period t
$\Delta ind_{hma,t}$ = change in the HMA index from period t-1 to period t
$nobs_{c,t}$ = number of observations in the centre during period t
$\Delta ind_{c,t}$ = change in the HMA index from period t-1 to period t

OGC

The change in the OGC index has been counted as the weighted average of the change in each city, where the number of flats in each city has been used as the weights:

$\Delta ind_{ogc,t} = \Sigma(dw_{i,t} * \Delta ind_{i,t}) / \Sigma(dw_{i,t})$

$\Delta ind_{ogc,t}$ = change in the OGC index from period t-1 to period t
$dw_{i,t}$ = number of dwellings in city i in period t
$\Delta ind_{i,t}$ = change in the city i index from period t-1 to period t
i = Jyväskylä, Oulu, Tampere, Turku

ROF

In the index for the whole country the change in the index is approximately the weighted average of the change in different regions in Finland, where the changes have been weighted by the total floor area of flats in each subregion. The change in the ROF index in each quarter has been estimated employing the following formula:

---

[23] All the data used in constructing the indices are from the Statistics Finland database. The data concerning the number of flats is annual. Linear interpolation has been used to estimate the number of flats in each quarter.

$\Delta ind_{rof,t} = [nfla_{country,t} * \Delta ind_{country,t} - \Sigma(nfla_{i,t} * \Delta ind_{i,t})] / (nfla_{country,t} - nfla_{i,t})$.

$\Delta ind_{rof,t}$ = change in the ROF index from period t-1 to period t
$nfla_{country,t}$ = number of flats in the whole country during period t
$\Delta ind_{country,t}$ = change in the index for the whole country from period t-1 to period t
$nfla_{i,t}$ = number of flats in area i during period t
$\Delta ind_{i,t}$ = change in the area i index from period t-1 to period t
i = HMA, the Satellites, OGC

APPENDIX 2 ADDITIONAL FIGURES AND TABLES

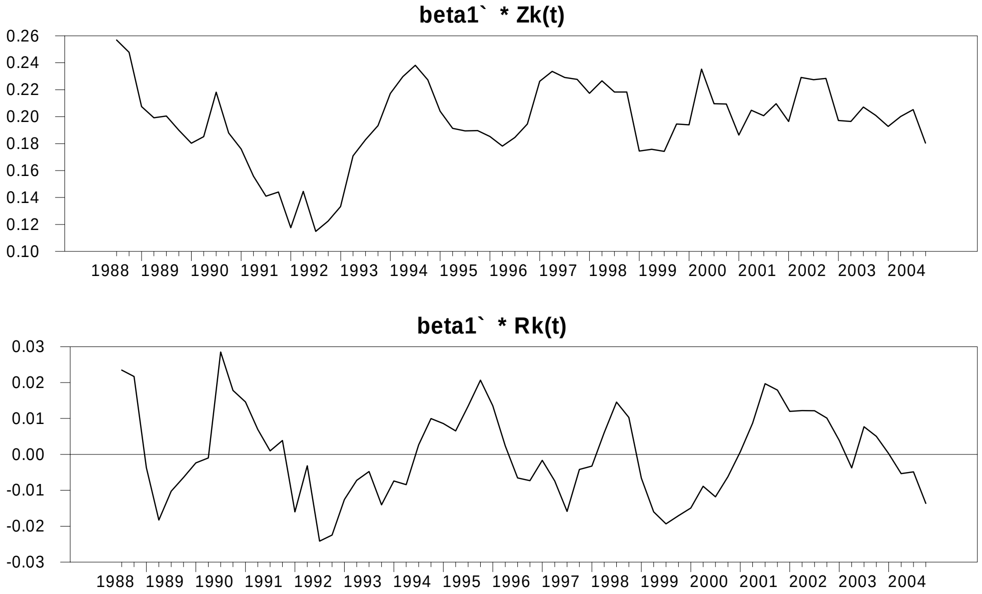

Figure A1 Disequilibrium from the cointegration relation between the HMA and the Satellites

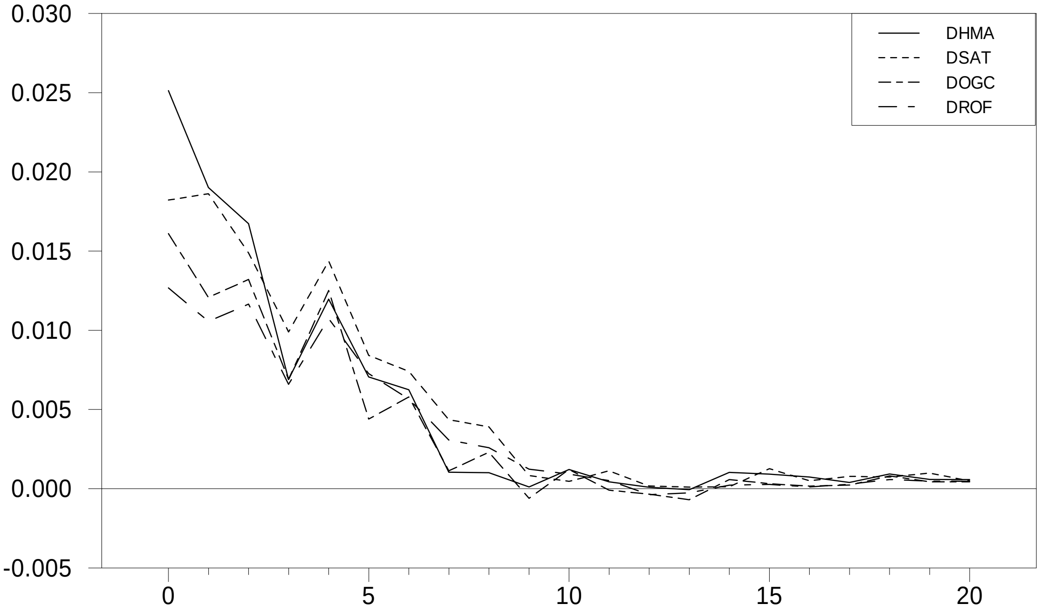

Figure A2 **Impulse responses to a one standard deviation shock in the ΔHMA based on the four variable model**

Table A1 **Augmented Dickey-Fuller test results**[24]

Area	Level (lags)	Difference (lags)
Centre of the HMA	-.044 (4)	-2.57* (3)
Other parts of the HMA	-.072 (5)	-2.89** (4)
Whole HMA	-.046 (5)	-2.84** (4)
Satellites	-.273 (5)	-3.07** (4)
Other growth centers	.024 (5)	-3.38** (4)
Rest of Finland	.240 (2)	-3.17** (4)
Turku	.198 (2)	-2.97** (1)
Rest of South West Finland	.224 (2)	-2.87** (1)
Tampere	.018 (5)	-3.20** (4)
Rest of Tampere Region	-.366 (5)	-2.83** (4)
Jyväkylä	.234 (2)	-3.13** (1)
Rest of Central Finland	-.369 (4)	-2.29* (3)
Oulu	.567 (2)	-3.08** (1)
Rest of Oulu Region	-.317 (4)	-2.40* (2)

---

[24] * and ** denote for five and one percent level of significance, respectively.

Table A2 Summary of the VECM including Turku and the rest of South West Finland

	ΔTurku		ΔSWF	
Constant	.002	(.03)	.175**	(3.69)
ΔTurku(1)	.272	(1.67)	.172	(1.61)
ΔSWF(1)	.490*	(2.44)	.181	(1.37)
β[25]			.291**	(3.70)
R^2	.35		.47	
Jarque-Bera	.88		.68	
LM(1) (system)	.37			
LM(4) (system)	.08			
Granger non-causality	.00		.07	

Table A3 Summary of the VECM including Tampere and the rest of Tampere Region

	ΔTampere		ΔTR	
Constant	-.103*	(-2.08)	.083*	(2.29)
ΔTampere (1)	.811**	(5.01)	.416**	(3.53)
ΔTampere (2)	.398*	(2.25)	.246	(1.90)
ΔTR(1)	-.411*	(-2.18)	-.379**	(-2.75)
ΔTR(2)	.249	(1.31)	.050	(.36)
Seasonal dummy 1	.017	(1.79)	.004	(.58)
Seasonal dummy 2	.042**	(4.04)	.031**	(4.04)
Seasonal dummy 3	.030**	(2.98)	.023**	(3.22)
β[26]	-.288*	(-2.10)	.233*	(2.34)
R^2	.57		.67	
Residuals (p-values)				
Jarque-Bera	.33		.05	
LM(1)	.85			
LM(4)	.23			
Granger non-causality	.00		.06	

---

[25] β = Turku(t-1) – 1.13*SWF(t-1) - .001t

[26] β = Tampere(t-1) – 1.09*TR(t-1) - .002t

Table A4 Summary of the near-VAR model including Jyväskylä and the rest of Central Finland

	ΔJyväskylä		ΔCF	
ΔJyväskylä(1)	.192	(1.74)	..414**	(4.02)
ΔJyväskylä(2)	.399**	(3.61)	.306**	(2.84)
ΔCF(1)			-.352**	(-2.95)
ΔCF(2)			-.027	(-.25)
R^2	.24		.30	
Residual analysis (p-values)				
Jarque-Bera	.29		.24	
LM(1)	.83		.32	
LM(4)	.32		.11	
Granger causality based on the fifth-order VAR (p-values, explanatory variable on the left)				
ΔJyväskylä	.06		.00	
ΔCF	.68		.04	

Table A4 Summary of the near-VAR model including Oulu and the rest of Oulu Region

	ΔOulu		ΔOR	
Constant	.018**	(2.78)	.014*	(2.55)
ΔOulu(1)	.386**	(3.35)	.235*	(2.43)
ΔOulu(2)	.253*	(2.20)	.425**	(4.17)
ΔOR(1)		(0.66)	-.210	(-1.90)
ΔOR(2)			.007	(.06)
Seasonal dummy 1	-.027**	(-2.78)	-.019*	(-2.33)
Seasonal dummy 2	-.018	(-1.84)	-.033**	(4.18)
Seasonal dummy 3	-.021*	(-2.22)	-.017*	(-2.31)
R^2	.36		.45	
Residual analysis (p-values)				
Jarque-Bera	.96		.64	
LM(1)	.31		.57	
LM(4)	.29		.31	
Granger causality based on the second-order VAR (p-values, explanatory variable on the left)				
ΔOulu	.00		.66	
ΔOR	.00		.23	

Table A2 Summary of the partial system VECM including the HMA, the Satellites, the other growth centres and the rest of Finland

	ΔHMA					ΔSat					ΔOGC					ΔROF					β[27]	drift
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)		
ΔHMA	.691*	.112	-.800*	.347	-.179	.285	.299	.556	-.036	-.145	.321	.556	.627	-.309	-.155	-.688	-1.23	-.530	.561	.243		-.001
	(2.46)	(.34)	(-2.50)	(1.13)	(-.58)	(.90)	(.90)	(1.69)	(-.11)	(-.49)	(.77)	(1.22)	(1.61)	(-.80)	(-.44)	(-1.00)	(-1.72)	(-.92)	(1.00)	(.53)		(-.02)
ΔSat	.269	-.250	-.867*	.078	-.492*	.325	.539*	.495	.251	-.092	.555	.567	.849**	.054	.262	-.660	-1.15*	-.623	.139	.030	.597**	-.106**
	(1.24)	(-.98)	(-2.51)	(.33)	(-2.05)	(1.32)	(2.09)	(1.94)	(1.01)	(-.40)	(1.72)	(1.61)	(2.81)	(.18)	(.95)	(-1.24)	(-2.07)	(-1.39)	(.32)	(.09)	(2.89)	(-3.02)
ΔOGC	.372	-.022	-.594*	.310	-.030	.134	.312	.422	-.172	-.159	.279	.041	.113	-.198	-.176	-.332	-.160	.006	.510	-.093		.002
	(1.73)	(-.09)	(-2.43)	(1.31)	(-.13)	(.55)	(1.22)	(1.67)	(-.70)	(-.70)	(.87)	(.12)	(.39)	(-.66)	(-.64)	(-.63)	(-.29)	(.02)	(1.18)	(-.27)		(.05)
ΔROF	.185	-.027	-.619**	.252	-.019	.309	.352	.301	-.074	-.133	.487*	.134	.267	-.190	-.017	-.597	-.401	.140	.366	-.139		-.001
	(1.13)	(-.14)	(-3.31)	(1.39)	(-.10)	(1.67)	(1.81)	(1.56)	(-.39)	(-.76)	(2.05)	(.50)	(1.17)	(-.84)	(-.08)	(1.48)	(-.96)	(.42)	(1.11)	(-.52)		(-.04)

P –values	ΔHMA	ΔSat	ΔOGC	ΔROF
R^2	.64	.78	.67	.76
Jarque-bera	.07	.11	.38	.11
LM(1) (system)[28]	.04			
LM(4) (system)	.02			
HMA does not Granger cause the other areas				.00
The other areas do not Granger cause the HMA				.91

---

[27] $\beta = HMA(t-1) - .951*SAT(t-1) - .003t$

[28] The LM(1) and LM(4) tests reject the hypothesis of no autocorrelation in the residuals. Nevertheless, plotting the residual autocorrelations and cross-autocorrelations implies that no more lags are needed in the model.

ELINKEINOELÄMÄN TUTKIMUSLAITOS (ETLA)
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
LÖNNROTINKATU 4 B, FIN-00120 HELSINKI

Puh./Tel. (09) 609 900 Telefax (09) 601753
Int. 358-9-609 900 Int. 358-9-601 753
http://www.etla.fi

KESKUSTELUAIHEITA - DISCUSSION PAPERS ISSN 0781-6847

Julkaisut ovat saatavissa elektronisessa muodossa internet-osoitteessa:
http://www.etla.fi/finnish/research/publications/searchengine

No 947 MARKKU STENBORG, Explaining Open Source. 11.11.2004. 34 p.

No 948 OLAVI RANTALA, Toimialojen T&K-panostusten ja tuottavuuden ennustejärjestelmä – Julkisen t&k-rahoituksen vaikuttavuus ja tuottavuuden pitkän ajan kasvu. 12.11.2004. 54 s.

No 949 CHRISTOPHER PALMBERG – OLLI MARTIKAINEN, The Finnish Telecom Sector Facing next Generation Standards – Indigenous Capabilities Versus R&D Alliances. 17.11.2004. 26 p.

No 950 ARI HYYTINEN – LOTTA VÄÄNÄNEN, Mandatory Auditor Choice and Small Firm Finance: Evidence from Finland. 22.11.2004. 31 p.

No 951 HANNU PIEKKOLA – MATTHIAS DESCHRYVERE, Retirement Decisions and Option Values: Their Application Regarding Finland, Belgium and Germany. 23.11.2004. 46 p.

No 952 TUOMAS MÖTTÖNEN, Turvallisuus ja kilpailukyky – kansainvälisten kilpailukykymittareiden valossa. 25.11.2004. 79 s.

No 953 SERGEY BOLTRAMOVICH – PAVEL FILIPPOV – HANNU HERNESNIEMI, The Innovation System and Business Environment of Northwest Russia. 07.12.2004. 47 p.

No 954 TUOMAS MÖTTÖNEN, Sotilaallinen T&K-panostus ja kilpailukyky. 25.11.2004. 29 s.

No 955 RAINE HERMANS – ANNE ARVOLA – LEENA HAUHIO – MAARIT LINDSTRÖM – HANNA NIKINMAA – PANU TIKKA – OLLI HALTIA, Bioteknologisten sovellusten arvonluonti Suomen metsäklusterissa. 03.12.2004. 28 s.

No 956 SATU NURMI, Employment Dynamics and Openness to Trade in Finnish Manufacturing. 01.12.2004. 28 p.

No 957 DEREK C. JONES – PANU KALMI – MIKKO MÄKINEN, The Determinants of Stock Option Compensation: Evidence from Finland. 01.12.2004. 32 p.

No 958 EDVARD JOHANSSON, Job Satisfaction in Finland – Some results from the European Community Household panel 1996-2001. 01.12.2004. 46 p.

No 959 HANNU PIEKKOLA – ANNI HEIKKILÄ, Active Ageing and Pension System: Finland. 07.12.2004. 35 p.

No 960 ANTTI KAUHANEN, Yrittäjien ansiot, työajat ja työkuormitus: Selvitys ekonomien ja insinöörien yrittäjyydestä. 09.12.2004. 22 s.

No 961 ANNI HEIKKILÄ, The Regional Distribution of Professional Competence in Finland. 16.12.2004. 20 p.

No 962 KARI E.O. ALHO, A Gravity Model under Monopolistic Competition. 31.12.2004. 15 p. Revised version 18.02-2005. 17 p.

No 963 KARI E.O. ALHO – VILLE KAITILA – MIKA WIDGRÉN, Speed of Convergence and Relocation: New EU Member Countries Catching up with the Old. 31.12.2004. 20 p.

No 964 MAIJA GAO – ARI HYYTINEN – OTTO TOIVANEN, Demand for Mobile Internet: Evidence from a Real-World Pricing Experiment. 11.01.2005. 39 p.

No 965 MIKA MALIRANTA, Foreign-owned firms and productivity-enhancing restructuring in Finnish manufacturing industries. 19.01.2005. 21 p.

No 966 CHRISTOPHER PALMBERG – MIKA PAJARINEN, Determinants of Internationalisation through Strategic Alliances – Insights Based on New Data on Large Finnish Firms. 28.01.2005. 22 p.

No 967 OLLI-PEKKA RUUSKANEN, Ajankäytön muutosten vaikutus työllistymishalukkuuteen. 01.02.2055. 21 s.

No 968 SERGEY BOLTRAMOVICH – VLADISLAV YURKOVSKY – PAVEL FILIPPOV – HANNU HERNESNIEMI, Russian Infrastructure Clusters. A Preliminary Study. 01.02.2005. 67 p.

No 969 PEKKA SULAMAA – MIKA WIDGRÉN, Economic Effects of Free Trade between the EU and Russia. 22.02.2005. 14 p.

No 970 HANNU HERNESNIEMI – KATI JÄRVI – JARI JUMPPONEN – GRIGORI DUDAREV – TAUNO TIUSANEN, Itäisen Suomen ja Venäjän liiketaloudellisen yhteistyön mahdollisuudet. 04.03.2005. 49 s.

No 971 JYRKI ALI-YRKKÖ – MONIKA JAIN, Offshoring Software Development – Case of Indian Firms in Finland. 07.03.2005. 14 p.

No 972 HANNU PIEKKOLA, Knowledge Capital as the Source of Growth. 17.03.2005. 35 p.

No 973 PEKKA YLÄ-ANTTILA – CHRISTOPHER PALMBERG, The Specificities of Finnish Industrial Policy – Challenges and Initiatives at the Turn of the Century. 29.03.2005. 25 p.

No 974 TUOMAS MÖTTÖNEN, Talouspoliittisen päätöksenteon tietoperustat. Esimerkkinä yritys- ja pääomaverouudistus. 29.03.2005. 90 s.

No 975 JYRKI LESSIG, Suhdannevaihteluiden symmetriaa kultakannan aikana. Ruotsin modernisoituminen, ulkomaankauppa ja taloudellinen integraatio 1800-luvun eurooppalaisten valuuttaliittojen aikana. 31.03.2005. 56 s.

No 976 SAMI NAPARI, Occupational Segregation during the 1980s and 1990s – The Case of Finnish Manufacturing. 18.04.2005. 54 p.

No 978 RAINE HERMANS – MARTTI KULVIK – ANTTI-JUSSI TAHVANAINEN, ETLA 2004 Survey on the Finnish Biotechnology Industries – Background and Descriptive Statistics. 22.04.2005. 40 p.

No 979 ELIAS OIKARINEN, The Diffusion of Housing Price Movements from Centre to Surrounding Areas. 25.04.2005. 36 p.

Elinkeinoelämän Tutkimuslaitoksen julkaisemat "Keskusteluaiheet" ovat raportteja alustavista tutkimustuloksista ja väliraportteja tekeillä olevista tutkimuksista. Tässä sarjassa julkaistuja monisteita on mahdollista ostaa Taloustieto Oy:stä kopiointi- ja toimituskuluja vastaavaan hintaan.

Papers in this series are reports on preliminary research results and on studies in progress. They are sold by Taloustieto Oy for a nominal fee covering copying and postage costs.