Economic shocks and growth: spatio-temporal perspectives on Europe's economies in a time of crisis

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Economic Shocks and Growth

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'Economic shocks and growth: spatio-temporal perspectives on Europe's economies in a time of crisis'

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Abstract: The response by regional and national economies to exogenous impulses has a well-established literature in both spatial econometrics and in mainstream econometrics and is of considerable importance given the current economic crisis. This paper focuses on dynamic counterfactual predictions and impulse-response functions to provide insight regarding the question of whether responses to economic shocks are transitory or permanent. Analysis shows that output shocks have permanent effects on productivity with economies adjusting to new levels following a shock. This suggests that the current recession will be embodied permanently within the memory of some of Europe's leading economies as a hysteretic effect.

Keywords : vector error correction, European Union, economic shocks, crisis, Verdoorn law, productivity

JEL codes : C32, C53, E27, R11

1. Introduction

The question of spillovers and contagion between economies is a highly relevant topic for study in this current era of globalized impulses and responses, and with the prospect of negative shocks in parts of the Eurozone threatening to affect the stability of the whole EU region, regardless of whether countries are Eurozone members or not, it seems timely to give some additional consideration to the possible mechanisms and routes of transmission, focussing on selected EU economies. One of the motivations for our paper is the work of Cerra and Saxena (2008) and Cerra, Panizza, and Saxena (2009), who look at the impact of shocks on national growth rates. Their work suggests that countries that have experienced economic disruption tend to lower growth rates over the long run. However, every country does not react in the same way, and the differentiated reaction to severe economic shocks in different countries may have an effect on the convergence or divergence of national economies. Thus we are interested in whether some EU economies' productivity[1] growth paths will be affected by the current severe downturn being experienced across the EU and other developed economies. To do this, we look at reactions to previous recessions, which may provide insights regarding relative economic vulnerability. We examine two aspects of the impact of shocks. First we look at the post-recession path of productivity relative to what we might expect given previous trends. Second, we look at the responses of economies to hypothetical shocks within their own economy, and in addition we consider responses to shocks spilling over from other economies. We ask the questions, are some economies more influential in terms of the responses they invoke, and, are some economies more exposed to negative spillover effects?

[1] Defined as GDP divided by employment.

The paper is also motivated by Fingleton, Garretsen and Martin (2012), who explore the regional rather than national dimensions of impulse response analysis, and also by the review of the concept of regional resilience by Martin (2012). One feature of Fingleton et al (2012), is the application of vector-error correction (VEC) models to produce forecasts and impulse-response graphs. In contrast, the use of vector autoregressive (VAR) models would embody a presumption of stationarity so that shock-effects are only transient. Our approach allows the possibility that shocks can have permanent effects. Indeed, our empirical analysis shows that shocks have permanent effects so that economies tend not to return to the pre-shock path but rather adjust to new levels. This indicates that the current recession will be embodied permanently within the memory of some of Europe's economies as a hysteretic effect, so that they are evidently being shifted permanently to different productivity paths.

To summarise, the original contribution of the paper is threefold. First, it extends the work of Cerra et. al. (2009, 2008), but differs significantly in that it is concerned with non-stationary series (i.e. uses VEC not VAR models). Thus it contributes to the hysteresis and resilience literature focussing on the potentially permanent, rather than transient, impact of shocks on subsequent growth. Second, it extends the work of Fingleton et. al. (2012) by modelling both GDP and employment levels combined to give productivity levels, applying this to the international level rather than being restricted to UK regions. And thirdly, it focuses on contagion and spillover effects, asking the question, ‘do shocks in neighbouring countries have a major effect domestically?’

2. Preliminary analysis

To illustrate the impact of the recession on the EU and US economies’ productivity, and on specific countries, we focus on the case of Ireland, which is a small open economy which one would anticipate would be quite exposed to external shocks. We frame our analysis through the lens of Verdoorn's law, which in its dynamic form posits a positive relationship between the rate of output growth and the rate of productivity growth. Verdoorn's law suggests economies of scale in production, such that higher levels of output result in higher levels of productivity. We focus on the effect of a negative shock to output on countries' productivity. In doing so this paper provides an empirical analysis of whether output shocks have a permanent or transitory effect on countries' productivity. Verdoorn's law, which can be traced back to Verdoorn (1949), is typically expressed as:

(1) $$r_j = r_a + \lambda g_j$$

Where r_a is the autonomous rate of growth, and r_j and g_j are the growth rates of labour productivity and output, respectively, for country *j*, and λ is the so-called Verdoorn coefficient, which typically takes a value of 0.5, implying increasing returns to scale (Angeriz, et al. 2008, Fingleton and McCombie 1998, McCombie 1983, Thirlwall 1983). We do not propose to estimate equation (1), but instead appeal to Verdoorn's law as the theoretical underpinning of our analysis[2]. Essentially we assess whether negative shocks to g_j, as a result of recessions, have a permanent effect on the growth path of r_j.

Consideration of Dixon and Thirlwall's (1975) circular causation model, which embodies the Verdoorn law, points to international interaction between productivity and output growth. The model can be summarised thus:

[2] Traditionally Verdoorn's law applies to the manufacturing sector, so there is only approximate concordance with our analysis which is at the level of the overall economy.

$$\begin{array}{lll} & \text{output growth} & g_{jt} = \gamma x_{jt} \\ & \text{export growth} & x_{jt} = \eta p_{jt} + \delta p_{ft} + \varepsilon z_{ft} \\ (2) & \text{domestic price growth} & p_{jt} = w_{jt} - r_{jt} + \tau_{jt} \\ & \text{productivity growth} & r_{jt} = r_{ja} + \lambda g_{jt} \end{array}$$

in which x_{jt} is domestic export growth, p_{jt} is the growth rate of domestic prices, p_{ft} is the growth rate of foreign prices and z_{ft} denotes real income growth in foreign markets. w_{jt} denotes domestic wage growth, r_{jt} is the average product of labour (in the export sector) and τ_{jt} is the rate of change of the mark up on labour costs. The subscript t indicates the time period. From this it is easy to show that if abs$(\gamma\eta\lambda) < 1$ then an equilibrium[3] exists at which

$$(3) \qquad \begin{array}{l} r_j = a_0 r_{ja} + a_1(w_j + \tau_j) + a_2 p_f + a_3 z_f \\ g_j = b_0(w_j - r_{ja} + \tau_j) + b_1 z_f + b_2 p_f \end{array}$$

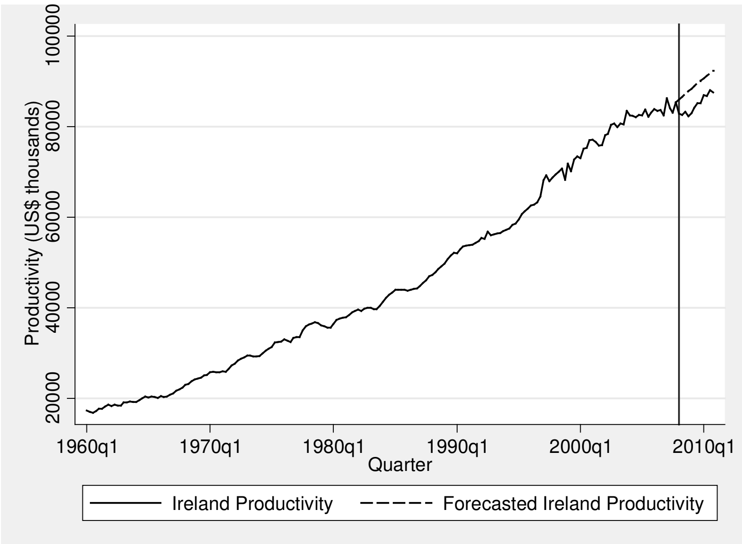
This shows that domestic productivity growth and domestic output growth depend on the growth of foreign prices and real income growth in foreign markets. While we do not formally embody the Dixon and Thirlwall (1975) model within our econometric model, it does suggest possible and plausible mechanisms of international contagion and transmission allowing a shock to foreign markets to have repercussions domestically.

Figures 1 through 3 display the actual and counterfactual level of productivity for Ireland, the EU15 and the US, with the solid vertical line representing the onset of the 2007 recession. If we examine Figure 1, we see the drop in Ireland's productivity since 2007q3. It could be suggested that the recession's impact in Ireland was more a reflection of internal conditions, with a bubble economy leading into 2007q3, than the shock itself. However while this might

[3] This is the general solution to a difference equation in g showing the transition dynamics to equilibrium when a single period time lag is introduced to one of the equations.

have contributed to the strength of the negative response, it is clear that the shock was a mainly exogenous phenomenon affecting economies across the globe rather than being principally the consequence of over-rapid internal expansion. For example, the EU15 economies were not expanding quite so fast, and yet we still see a significant downturn in relation to expectation after 2007q3, likewise the US economy (see Figures 2 and 3)[4].

Figure 1: Actual and counterfactual quarterly Productivity series for Ireland



[4] The dynamic forecasts in Figures 1 are based on the estimates of a VEC model with two cointegrating vectors and two lags, with GDP and employment series for Ireland, EU-14 and the US. The forecasts in Figure 2 and 3 are based on the estimates of a VEC model with three cointegrating vectors and one lag with GDP and employment series for the US and the EU-15. Productivity is calculated following the estimation of the VEC models as GDP/employment.

Figure 2: Actual and counterfactual quarterly Productivity series for EU15

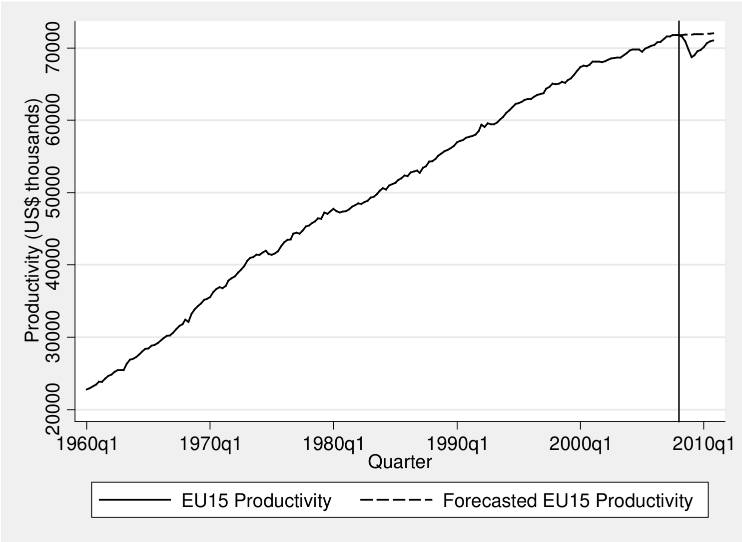
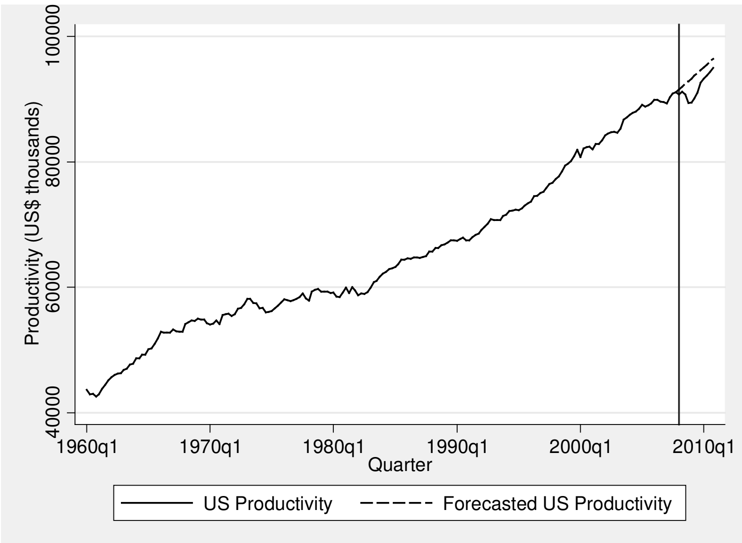


Figure 3: Actual and counterfactual quarterly Productivity series for the US



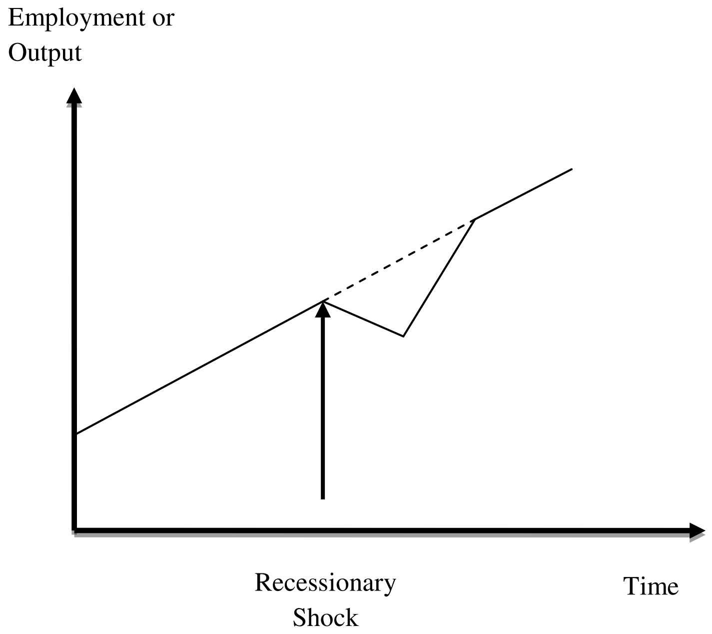
We explore data for major EU economies by fitting a (suite of) VEC model(s) to give the likely post-recession counterfactual path. We look at the historical evidence going back to the recession of the early 1990s (or in the case of Ireland the 1980s) in order to examine what the data tell us about shock impacts. Subsequently, we show that shocks to one economy spill over to others with differentiated impacts that do seemingly reflect differing internal conditions. With negative shocks, we might say that some economies are more exposed than others to outside shocks; on the other hand a positive boost to an outside economy may have greater benefits internally. Thus our analysis of Ireland, which is a small, open economy, is particularly interesting, because it is more likely to be more vulnerable, but on the other hand is likely also to benefit more from a surge in growth in other economies.

3. Hysteresis

We are interested in the following questions. What is the likely long term effect of this most recent shock? Will it produce a permanent reduction in productivity, or will it have the effect of stimulating productivity as an outcome of a process of creative destruction. By considering the response of productivity to output shocks we are implicitly considering the response of output and employment to output shocks as productivity is given as output divided by employment. Our model embodies the possibility of hysteresis, which is a long established concept transgressing the various sciences which typically has been applied to explain the persistence of negative shocks to unemployment. Thus according to Blanchard and Summers (1987) "the development of alternative theories of unemployment embodying the idea that the equilibrium unemployment rate depends on the history of the actual unemployment rate. Such theories may be labelled hysteresis theories after the term in the physical sciences referring to situations where equilibrium is path-dependent" (pp 290). Thus a negative shock leading to permanently higher unemployment may occur if the long term unemployed lose skills and miss out on job training, so that they ultimately become unemployable. In contrast, the employed continue to benefit from learning-by-doing. This viewpoint of hysteresis in unemployment is supported by Jaeger and Parkinson (1994) and Jacobsona, Vredinb and Warne (1997).

More recently Paul Krugman (2011) has argued that "there is a real concern that if the slump goes on long enough, it can turn into a supply-side problem, because investment will be depressed, reducing future capacity, and because workers who have been unemployed for a long time become unemployable". Thus "hysteresis can mean that the costs of failing to pursue expansionary policies are much greater than even the direct effects on employment. And it can also mean, especially in the face of very low interest rates, that austerity policies are actually self-destructive even in purely fiscal terms: by reducing the economy's future potential, they reduce future revenues, and can make the debt position worse in the long run" (Krugman 2011).

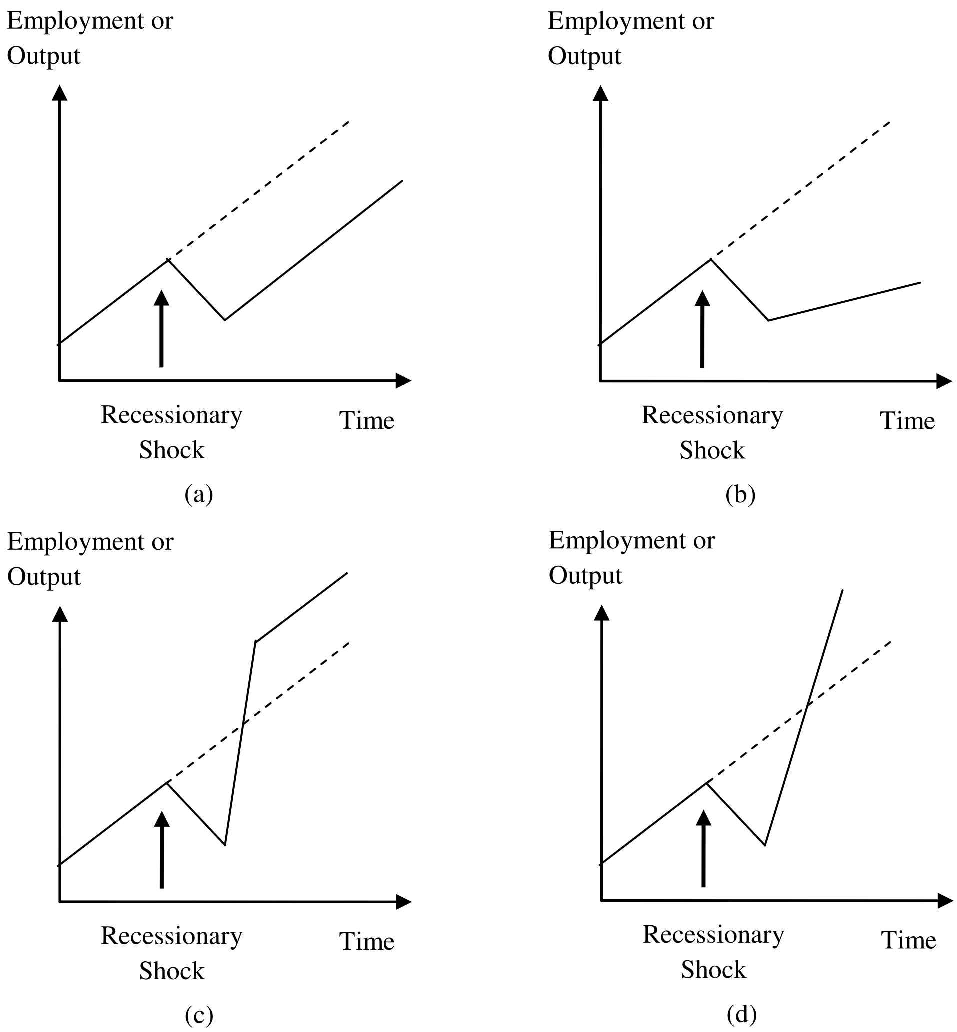
Figure 4: Anti-hysteresis



The opposite of hysteresis, or what we term anti-hysteresis, is embodied in Friedman's (1964, 1993) so-called plucking model, which assumes that shocks are temporary in nature and have no permanent effect on an economy's long-run growth ceiling or growth trend (see Figure 4). This return to the pre-shock growth path is not what we anticipate for the EU economies, with the prospect of long-term 'damage' as the result of a negative shock, although a negative shock could also produce long-term positive benefits. Martin (2012), Fingleton et al. (2012) and Cross et al. (2009) note that it is possible to envisage a number of different possible hysteretic outcomes of a shock and that the outcome may depend on the variable considered as well as the underlying structure of the economy. Cross et al. (2010) appeal to a Schumpeterian point of view of creative destruction to explain these hysteresis effects.

Two possible negative hysteretic outcomes can be identified. In the first instance, the shock causes a downward shift in the variable's growth path, but the growth rate returns to pre-shock levels. This may result from a shock destroying a significant proportion of the economy's productivity capacity and jobs. This is depicted in Figure 5(a). The second negative outcome is where, not only is there a downward shift in level, but also a reduction in growth rate. This may result from the destruction of large sections of an economy's industrial base which may have a negative multiplier effect on other sectors. This is displayed in Figure 5(b). Two positive hysteretic reactions can also materialise following a negative shock. In both instances, the economy more than rebounds from the shock and initially experiences rapid growth, in excess of the pre-shock rate, following the initial downward effects of the shock. This may be due to optimistic business expectations, the availability of spare capacity to expand, or new firm foundations. The distinction between the two possible positive hysteretic effects is whether the post-shock growth rates can be maintained. If the scope for continued rapid expansion becomes exhausted, the economy may return to pre-shock growth rates, albeit at a higher level. This is depicted in Figure 5(c). However, if the economy can maintain the post-shock growth rates this implies continued growth at a rate in excess of the pre-shock rate. For instance the shock may have released productive resources that were formerly employed in other now defunct low growth and low productivity sectors, causing permanently faster output and productivity growth than hitherto. This is depicted in Figure 5(d).

Figure 5: Stylised Responses to Shocks



Source: redrawn from Fingleton et. al. (2012)

4. The data

Our analysis focuses on using employment and GDP series over the period from 1960q1 to 2011q1 to study the impact of shocks to GDP on productivity. The quarterly data for GDP for all the EU countries and the US are obtained from the OECD's historical quarterly national accounts series. In order to derive a quarterly historical time series the most recent OECD national accounts are linked to older historical series. The method utilised to link the differing series, which on occasion are assembled using different methodologies, starts by identifying the ratio between the newest series and the older series in the first common year. This ratio is then multiplied along the older series to render it comparable to the newest series. This method is applied across all breaks in methods for all countries (OECD 2011b).

The data are converted by the OECD into US dollars and are adjusted for purchasing power parity (PPP). Specific PPPs are utilised to convert European countries' GDP and its components in national currencies into US dollars. When converted by means of PPPs, the expenditure on GDP for different countries is measured using the same set of international prices so that comparisons between countries reflect only differences in the volume of goods and services purchased. National converted data can then be aggregated to obtain aggregates for groups of countries, which are expressed at the same set of international prices (OECD 2011a).

While data is available for GDP from 1960q1 to 2011q1, quarterly employment data are not as readily available. Employment data for the US and Italy are available quarterly back to 1960, however, this is not the case for the remaining fourteen countries considered. In the case of Ireland, data is only available from 1997 to present. However, annual employment figures are available from 1960 for all countries contained in the sample from the Total Economy Database (The Conference Board 2012). This presents an opportunity to construct quarterly employment series for all countries going back to 1960q1 using the Chow-Lin best linear disaggregator. A brief summary of this procedure is presented in the Appendix A1.

5. The model

Following the empirical framework adopted by Fingleton et al. (2012), we attempt to capture the likely effects of negative shocks on productivity econometrically by our implementation of VEC models, which are designed to model nonstationary series. As a prelude to our VEC modelling exercise, we test for unit roots in our employment and GDP series, and from this show that shocks to these series do have permanent rather than transient effects, as implied by the VEC model. Details of the Dickey-Fuller tests for the VEC models estimated by this paper are presented in the Appendix A2., for the full time period from which the IRFs are derived, and Appendix A3., for the sub-periods modelled to generate the dynamic forecasts for the counterfactual productivity levels.

5.1 Specification

Our counterfactual prediction of productivity levels and of the impact of hypothetical shocks depends on the underlying VEC model being an accurate description of reality. The VEC model specification is determined by the number of lags in the model (the order) and by the rank of the long-run response matrix, in other words the number of linearly independent rows, as indicated by the number of non-zero eigenvalues (or characteristic roots) or cointegrating vectors. In each of the VEC models there are six series, so the rank is the number of independent cointegrating relationships between these six series. Having determined the number of lags[5], we consider the outcome of applying the so-called Pantula principle (Pantula 1989) used by Johansen (1992), Hansen and Juselius (1995) and others to identify the exact model structure including the rank. The Pantula principle allows a joint test of whether there are deterministic variables (a trend and constant) within the cointegration space together with a test of cointegration rank. However it is not a panacea for model choice (Doornik, et al. 1998, Hjelm and Johansson 2005). In their Monte Carlo study, Hjelm and Johansson (2005) find that the Pantula principle is "heavily biased towards choosing the model with an unrestricted constant when the model with a restricted trend is the true one" (pp. 691). Accordingly, rather than confine analysis to a single, 'optimal' model for each country chosen via the Pantula principle, we also estimate a range of different supplementary models with different orders and different ranks. From this we can indicate the degree of robustness of our predictions and impact analysis to model misspecification.

[5] See Appendix A4., Tables A.4 and A.5 for details.

Consideration of the issues surrounding the application of the Pantula principle points us towards specifications that appear to be feasible for our data. The approach involves a sequence of nested models based on restrictions on the full model, as given in equation (4). It starts with the most restrictive specification and moves through to the least restrictive, testing whether the number of cointegrating vectors satisfy $r = 0$. Then we repeat, moving across from most to least restrictive specification, checking for $r = 1$, and so on repeating for $r = n - 1$, where $n = 6$ series[6]. For each test the null hypothesis is that the true rank $\leq r$, in other words that the columns of β in equation (4) greater than r are null. The alternative is that $r <$ rank $\leq$ full rank. Thus the trace test compares the likelihoods of the rank r model and the full rank model. If the difference is significant, we cannot assume that the true rank is r and eliminate higher ranks. If the difference is not significant, we assume that the rank is r. Going through the sequence of model comparisons, the stopping point is the first occasion on which we 'accept' the null that the rank $\leq r$.

(4) $$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + ... + \Gamma_{k-1} \Delta Z_{t-k-1} + \mu_1 + \delta_1 t + \mu_t + \alpha(\beta' Z_{t-1} + \mu_2 + \delta_2 t)$$

Equation (4) is the full, unrestricted model in which Z_t is an n x 1 vector comprising six endogenous variables observed at time t, namely a (target) country's log GDP and log employment levels, the log of aggregate GDP and employment in the other 14 countries of the EU15 (which we refer to as EU14, although of course this variable changes as we change the 'target' country excluded from EU15), and log GDP and log employment levels in the US. The Γs are n x n matrices, μ_1 and δ_1 are n x 1 vectors or parameters, and u_t is an n x 1 vector of disturbances. Also α and β are n x r rank matrices, so that μ_2 and δ_2 are r x 1

[6] Failure to reject $r = 0$ implies that the appropriate model is a VAR in stationary first differences. On the other hand rejecting all hypotheses regarding r implies that the data are stationary in levels, i.e. Z~I(0).

vectors of parameters. Since the variables are in logs, the first differences ΔZ_t are exponential growth rates.

The number of lags *k* is first identified by fitting VAR models, which are mathematically equivalent to VEC models with full rank[7]. Given K we can proceed to consider, jointly with the determination of rank, hypotheses about the inclusion or exclusion of the constant terms μ_2 and the trend terms $\delta_2 t$ in the long run cointegrating vector (CE), and the presence or absence of the constant terms μ_1 and trend terms $\delta_1 t$ in the short run (VAR) model.

There are 5 possible models which can be obtained by placing various restrictions, or none, on the parameters of equation (4) and comparing likelihoods[8]. Assume that we restrict both the VAR and the CE (corresponding to the terms within brackets), so that there is no constant and time trends in either, hence $\mu_1 = \delta_1 = \mu_2 = \delta_2 = 0$. This would only be appropriate if each variable had zero mean. Similarly, we can exclude consideration of the totally unconstrained model in which $\mu_1 \neq 0, \delta_1 \neq 0, \mu_2 \neq 0, \delta_2 \neq 0$, even though this is likely to fit the data quite well. It implies quadratic trends so that if the variables are entered as logs, as in our case, this implies ever increasing or every decreasing rate of change and one which is

[7] The results of the SBIC tests applied to each VAR model are displayed in Appendix A4. It can be noted that for the full sample Ireland, Germany, France and Italy models an optimal lag length of two is identified whereas for the UK an optimal lag length of one is identified. For the sub-periods lag lengths of two apply for Ireland and Germany and one for the remaining countries.

[8] The log likelihood for the VEC is derived assuming the errors are independently and identically distributed (i.i.d.) normal. However normality can for practical purposes be replaced by weaker assumptions that the errors are merely i.i.d , since these alone support many of the asymptotic properties that are the basis of our inferences (Johansen, 1995).

likely to produce poor out-of-sample forecasts. There is also some discussion in the literature about the general plausibility of model (5), in which $\mu_1 = \delta_1 = \delta_2 = 0$, in macroeconomic analysis because of the exclusion of linear trends, so we exclude this so-called restricted constant model from consideration, leaving us with models (6) and (7), namely the models with unrestricted constants in both CE and VAR components, and restricted trends in the VAR component involving differenced data respectively. However even here there is reason to doubt the validity of the trace test used to compare models (6) and (7) (Ahking 2002, Hjelm and Johansson 2005, Johansen 1995). Johansen (1992) only suggests the use of the Pantula principle for choosing between Models (5) and (6). This therefore casts some doubt on the Pantula principle as a valid model selection procedure, although the issues relating to its application do point to the consideration of just two feasible rivals, namely models (6) and (7):

(5) $$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_{k-1} \Delta Z_{t-k-1} + u_t + \alpha(\beta' Z_{t-1} + \mu_2)$$

(6) $$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_{k-1} \Delta Z_{t-k-1} + \mu_1 + u_t + \alpha(\beta' Z_{t-1} + \mu_2)$$

(7) $$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_{k-1} \Delta Z_{t-k-1} + \mu_1 + u_t + \alpha(\beta' Z_{t-1} + \mu_2 + \delta_2 t)$$

These models are increasingly less restrictive. In the case of (5), which has a (restricted) constant within the cointegration space $\mu_1 = \delta_1 = \delta_2 = 0, \mu_2 \neq 0$, there are no time trends in the model, and only intercepts in the CE, with none in the VAR. We exclude further consideration of this model. The model (6) specification with (unrestricted) constants entails that $\delta_1 = \delta_2 = 0, \mu_2 \neq 0, \mu_1 \neq 0$ hence it contains no trends in either VAR or CE, but each has intercepts. With differences in logs, this implies constant growth in levels and hence this model is a plausible option. Likewise model (7) has (restricted) trends within the cointegration space so that $\delta_1 = 0, \delta_2 \neq 0, \mu_2 \neq 0, \mu_1 \neq 0$, hence there are intercepts in both VAR and CE, and trends in CE but no trends in VAR. The trend in CE therefore picks up some additional growth that is not captured by (6).

5.2 Results

Our chosen models on which our predictions and impulse-response analysis are based are versions of models (6) and (7) with an appropriate rank and order. The selected, or more or less 'typical', models are highlighted in Appendix A5 alongside the results of the Johansen trace tests for each VEC model estimated. Although we choose models for which the null hypothesis rank $\leq r$ is not rejected, additional predictions and response functions of different specifications are illustrated in Appendix A6. We show a panoply of outcomes because of the criticism that can be laid against formal application of the Pantula principle, as outlined above. In cases where different specifications produce essentially the same outcomes as are produced by our preferred model, we can be more confident in our interpretations than in cases where there is more variability in outcome. Therefore, the alterative traces on our graphs allow us some form of quality control, enabling us to weigh our interpretations below according to their relative stability across different specifications.

6. Actual and counterfactual responses to shocks

This section presents historical evidence of the response of Ireland, Germany, the UK, France and Italy's productivity to recessionary shocks. The counterfactual and actual productivity series for each country following a recession are displayed in Figure 6. As the onset of recessions occur at different times in each country, VEC models based on different time periods must be analysed. For Ireland, which barely showed signs of recession in the 1990s, the recession chosen commenced in 1982q3. The other countries went into recession at different times in the 1990s, commencing with 1990q2 for the UK, 1992q1 for Germany, finally 1992q2 for France and Italy. As stated previously, while the results presented here are based on one preferred model, a series of alternative models are estimated to indicate the degree to which our analysis is robust to model respecification. The dynamic forecasts generated from these alternative specifications are presented in Appendix A6, Figure A.1.

6.1 Response of Productivity to Recession

Figure 6 shows actual and counterfactual quarterly productivity series, with the counterfactual growth rates based on dynamic forecasts showing the hypothetical growth path of productivity for the country should the recession not have occurred[9]. Of interest to us is whether actual productivity remains permanently lower than the counterfactual productivity, signifying a permanent fall in productivity, or whether the actual level returns to or exceeds the counterfactual level. If productivity remains below its counterfactual level or indeed rises above it a hysteretic effect can be deemed to have occurred, where the recessionary shock has resulted in a permanent lowering/raising of the country's productivity growth path.

As Ireland barely suffered a recession in the 1990s the more severe 1980s recession is used. It can be observed that following the recession productivity in Ireland dipped temporarily but appears to return to the pre-shock productivity level. This is not dissimilar to anti-hysteresis (Figure 4), since Irish productivity more or less returns to its pre-shock growth path, implying only transient shock effects that fade away over time. However, during the late 1990s and following the current crisis Ireland again falls below the counterfactual productivity forecast.

A similar pattern emerges for the other four countries considered. Following the recession, actual productivity falls away from the counterfactual level but in the case of Germany,

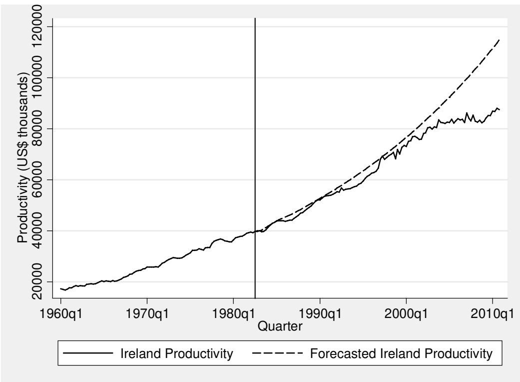
[9] Based on coefficient estimates from our preferred specifications obtained from the data prior to the onset of recession.

France and Italy it remains permanently lower. This suggests that the recessions experienced by these three countries resulted in a permanent lowering of the productive ceiling, implying that the shocks had a negative hysteretic effect. However, in the case of the UK, actual productivity quickly converges with the counterfactual figures after approximately two quarters, and subsequently superseded the counterfactual level. This suggests that the UK economy responded differently to the recessionary shock of the early 1990s than the other countries considered. The picture emerging for the UK's productivity path is not unlike Figure 5d which shows the eventuality where the creative elements of a recession outweigh the destructive elements (Cross, McNamara and Pokrovskii 2010). This may be partly the result from optimistic business expectations, the availability of spare capacity to expand or new firm foundations. However the fundamental reason is the shake-out of employment, with jobs evidently being replaced by capital and to a greater extent than in the other economies, rather than there being a surge in production and productive capacity. This is the story told by the equivalent graphs[10] of employment and of GDP. While the UK's GDP tracked expectation fairly closely, employment fell permanently below expectation, the net outcome being above expectation productivity levels through the projection period. In contrast, in the post-recession period, employment levels in Germany, France and Italy were closer to and even exceeded the counterfactual expectations, whereas GDP remained below the counterfactual. Because it is an outcome based largely on lower employment than expected, despite the positive hysteretic effect on productivity we are reluctant to suggest that the UK economy was more resilient than that of Germany, France and Italy to the recessionary shock in the 1990s.

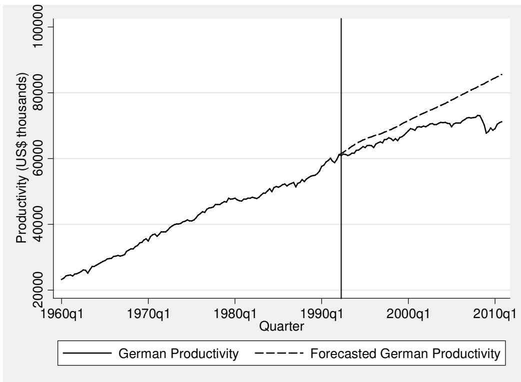
[10] To save space we have omitted the GDP and employment counterfactuals series.

Figure 6: Actual and counterfactual quarterly Productivity Series – 1990s Recession

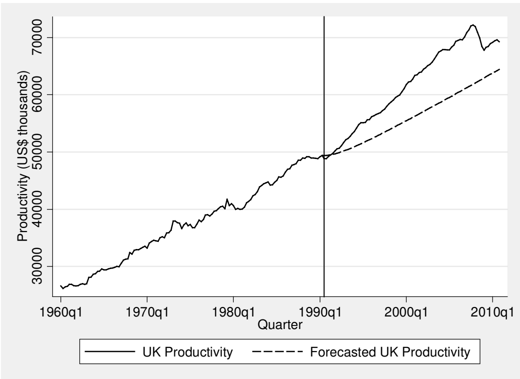
Ireland



German



UK



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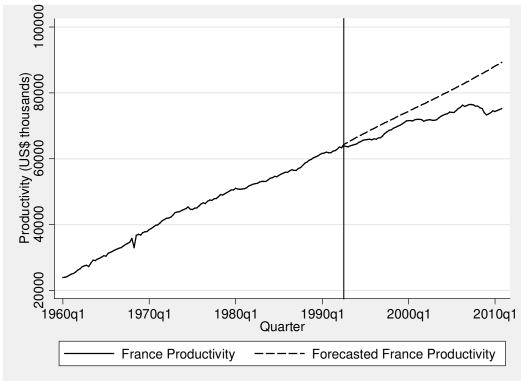
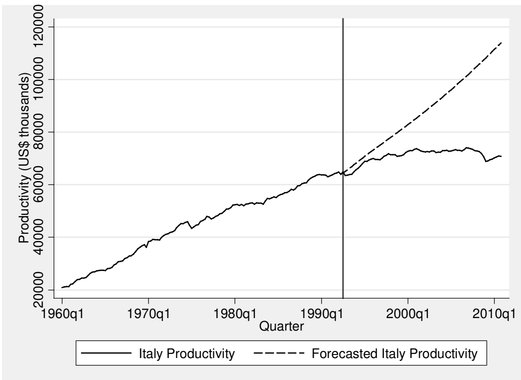


Italy



7. Impulse-response analysis

Our impulse-response analysis is based on orthogonalized impulse response functions (OIRFs) which measure endogenous variables' responses to a hypothetical one unit (one standard error) shock to one specific endogenous variable occurring at one instant in time. Orthogonalization eliminates contemporaneous correlation and we can therefore 'shock' one variable without 'shocking' others, thus allowing a causal interpretation. To achieve this we invoke a recursive structure corresponding to the ordering of the Cholesky decomposition of the cross-equation covariance matrix (Enders 2010). However, because the identifying restrictions are arbitrary, with different Cholesky decomposition orderings possible, there are different possible outcomes, although we find that outcomes are robust to different orderings.

In order to identify the responsiveness of countries to shocks originating from within and outside the country, IRFs are derived which show the impact of (i) internal shocks, (ii) shocks from other EU countries and (iii) shocks from the US. Shocks originating in both GDP and employment can be considered, but in line with our Verdoorn law motivation, we limit our analysis here to the impact of shocks to GDP on productivity. The use of IRFs allows us to assess whether impulses from outside countries are stronger or weaker than local impulses. Secondly, we assess the relative permanency of the response of productivity to GDP shocks.

7.1 Impact of a Shock to GDP on Productivity

The response of countries' productivity to a hypothetical negative one standard error shock in GDP can be observed in Figure 7. The broad conclusions are as follows. First, we find that the effects of a shock, irrespective of source, are always negative in the short run. Secondly, domestic shocks mainly have a permanent negative effect. Thirdly, in the long run the negative effects of shocks emanating from neighbouring European economies tend to dissipate. Finally, shocks with origins in the US generally have a permanent negative effect. Of course these are generalizations, and looking in detail we see immediately that there is substantial variation in how countries respond to shocks in terms of response magnitudes, sensitivity to internal and external shocks, the persistence or transience of these shock effects and also whether the shocks have positive or negative long-run effects on productivity.

Starting with Ireland, Figure 7 indicates that GDP shocks, regardless of their origin, clearly have permanent negative effects on Irish productivity, an interpretation generally reinforced by the alternative (less preferred) model outcomes in Figures A.2 through A.4. Domestic GDP shocks have the largest negative effect on Irish productivity. The spillover effect of a shock to US GDP produces a less intense negative response, and while remaining negative, the long-run response is only just negative but our alternative models (Figure A.2) generally support the view of a negative long-run response. Shocks originating in the EU-14 also have a permanent negative effect on Irish productivity but, while the initial response is slightly positive, in the longer run the response is negative. However, Figure A.3 shows that our alternative models exhibit some ambiguity relating to the response in the long-run. The evidence suggests that Ireland may be more sensitive to GDP shocks originating in the domestic economy followed by other EU countries and finally the US economy. Although due to variations in the alternative model specifications we are less confident in our EU shock interpretation.

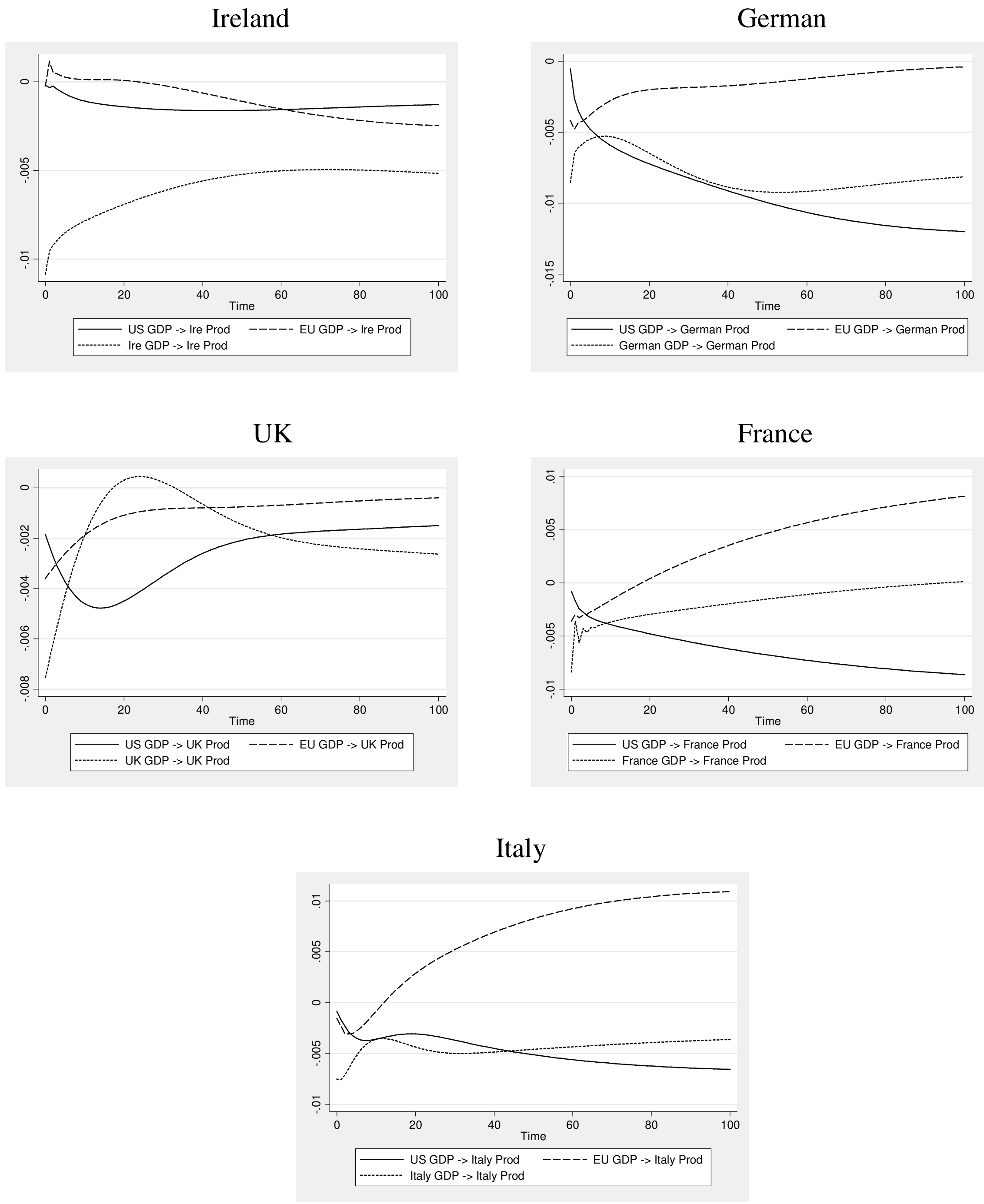
Turning to Germany, Figure 7 shows that while domestic GDP shocks and GDP shocks originating in the US have permanent negative effects on productivity the relative magnitude is reversed compared with Ireland. Shocks from the US have a deeper negative effect than domestic shocks suggesting that, unlike Ireland, Germany is evidently more susceptible to outside shocks as opposed to domestic shocks. This is interesting, because one would suppose that Ireland was much more susceptible to external shocks, and the large German economy was more insulated. However, while Figure A.2 reinforces the view that a US GDP shock has a permanent negative effect on German productivity, our preferred model is definitely more pessimistic than almost all the alternative models considered, while the prediction of our preferred model of the Irish productivity response is in the middle of all the alternatives considered, so the deeper response in Germany may not be so profound as Figure 7 indicates. Interestingly, the response of German productivity to a negative GDP shock in EU14 is mainly transient with no long-run impact. Like some other countries, Germany is relatively immune to negative external shocks originating from the EU, with no apparent long-run impact on productivity. This prediction is fairly central to the range of reasonably clustered outcomes from our alternative specifications shown in Figure A.3.

As in the case of Ireland, for the UK, our preferred simulations show that domestic shocks have a larger negative effect than US or EU shocks, although again the prediction is towards the bottom of the range of outcomes in Figure A.4. US shocks also evidently have a persistent but smaller negative effect on productivity. Figure 7 shows that in the long-run shocks originating in the EU14, while initially negative, once again mainly dissipate so that the long-run consequence for productivity is negligible. Figure A.3 shows that some alterative specifications produce the same outcome, but some (less preferred) models predict a more positive long-run response.

A negative shock to US GDP also has a large permanent effect on the French economy, relative to a domestic or EU GDP shocks, clearly reducing productivity in the long-run. Somewhat in contrast, a negative GDP shock in the neighbouring EU economies produces positive long-run consequences for French productivity, which is an outcome that is not confined to our preferred specification (see the alternative projections in Figure A.3). However, a negative domestic shock to France's GDP is tending towards no long-term negative consequences for productiivity, an interpretation supported by almost all outcomes in Figure A.4. The possibly transient nature of the impact of a domestic GDP shock is unusual compared with outcomes for our other countries.

Italy is similar to France in that shocks originating from the US have the largest negative effects on Italian productivity. However, the consequences of a shock to domestic GDP are also evidently negative in the long-run, tracing a similar path to the US impulse. Italy, like other countries, suffers no long term negative effects from EU shocks, indeed like France it actually experiencing a permanent increase in productivity. These conclusions are supported by the alternative specifications presented in Appendix A6.

Figure 7: IRF – Countries' Productivity Responses to a Negative one Standard Error Shock to GDP



8. Conclusions

This paper analyses how selected EU economies' productivity growth paths have been affected by previous recessions and uses this to cast light on how the current economic downturn being experienced across the EU and other developed economies may impact on their subsequent productivity. The paper firstly looks at the post-recession path of productivity relative to counterfactuals based on pre-recession trends. Secondly, it analyses the responsiveness of economies to hypothetical domestic and external GDP shocks, addressing the question of which of domestic, US or neighbouring EU economies are more influential in terms of the responses they invoke, and, whether some economies are more exposed than others to negative spillover effects.

Five European countries are analysed; Ireland, Germany, the UK, France and Italy. Quarterly GDP and employment figures from 1960q1 to 2011q1 are utilised. A series of five preferred VEC models are estimated which include each of these countries' GDP and employment, US GDP and employment and an aggregate of the EU15 countries' (excluding the individual country considered) GDP and employment. From the resulting models we obtain dynamic forecasts and impulse response functions showing the impact of GDP shocks on productivity.

Comparing post-recession outcomes with counterfactual series suggests varying responses to recession. Evidence suggests that the recessions experienced by Germany, France and Italy in the 1990s resulted in these countries' productivity shifting to a lower growth path. However, UK and Irish productivity recover from the recessionary shocks they experienced, with the UK even performing above expectation. This suggests a strong heterogeneity in the response of European countries to recessionary shocks.

Subsequent analysis using IRFs allow a more detailed analysis of varied outcomes which depend on the source of the shock and the country affected, although the short-run impact of a shock to GDP from any source is invariably negative for productivity. One common element among the countries is that shocks originating from the US have a permanent negative effect. In the case of all countries bar Ireland, this negative response to US shocks is greater than shocks originating in the EU. This suggests that the EU countries considered appear to suffer more from shocks originating in the US than shocks originating in their European neighbours. The relative importance of domestic and external shocks also varies across countries. While Ireland and the UK are most vulnerable to domestic shocks, Germany, France and Italy are more responsive to shocks from the US. These results suggest that the ability of countries to rebound from shocks is predicated upon the origin of the shock experienced and the specific country. The results suggest that two countries, which experience the same types of shock, may have substantially different long run outcomes resulting from the shock. The reasons for the differentiated responses are, we suggest, very much related to the industrial structure of each country and to the size and diversity of economies. It appears that larger economies, such as Germany, the UK, France and Italy bounce back and productivity is enhanced in the long-run when subject to a negative impulse from the surrounding 14 EU economies, as though within the EU-14 negative output shocks decimate domestic productive capacity and the larger economies gain in the long-run, capturing neighbours' markets post-recession whenever domestic productive capacity is reduced. This would be consistent with the increasing returns to scale story embodied with our Verdoorn law which provides a theoretical context for our empirical analysis. Industrial structure is also important because some economies are more cyclically sensitive than others, typically those dominated by manufacturing may be more prone to the vagaries of the economic cycle. We do however add a word of caution, because our analysis, which is predicated on average impulse-response reactions over the entire quarterly series going back to 1961Q1, masks the dynamical structural changes that are probably occurring in each country in response to earlier shocks. Thus vulnerability in some sectors to negative shocks, and positive growth in other sectors in response to positive shocks, is very likely to be changing the structural composition of each country over time, and thus also changing the country's resilience to economic shock. What we have shown in the paper is that on average there appear to be differences in economies resilience to shock which are a fairly long-lasting feature that is evident through the time series we have available. Further more detailed analysis taking account of on-going dynamical structural change is the subject of another paper.

Appendix

A1. Generating Quarterly Employment using the Chow-Lin Procedure

Quarterly data on employment for the majority of the sixteen countries (EU15 plus the US) considered by this paper are only available for shorter periods of time than the quarterly GDP figures obtained from the OECD's historical quarterly national accounts, which are available from 1960q1 to 2011q1. Table 1 displays the availability of employment data.

Table A.1: Availability of Quarterly Data Series

Country	United States	Germany	United Kingdom	France	Italy	Spain	Netherlands	Belgium
Start of Data	Q1 1960	Q1 1962	Q2 1969	Q1 1995	Q1 1960	Q3 1972	Q1 2000	Q1 1999
End of Data	Q1 2011	Q1 2011	Q1 2011	Q1 2011	Q1 2011	Q1 2011	Q1 2011	Q1 2011

Table 1: Availability of Quarterly Data Series (con.)

Country	Austria	Greece	Portugal	Norway	Denmark	Finland	Ireland	Luxembourg
Start of Data	Q1 1969	Q1 1998	Q2 1983	Q1 1972	Q1 1995	Q1 1964	Q4 1997	Q1 2003
End of Data	Q1 2011	Q1 2011	Q1 2011	Q1 2011	Q1 2011	Q1 2011	Q1 2011	Q1 2011

Note 1: Source OECD Employment data series
2: Quarterly data for Luxembourg is actually also available from Q1 1985 to Q4 1997 however there are gaps in the data series between Q4 1997 and Q1 2003.

However annual series are available, Chow and Lin (1971) develop a procedure for converting annual into monthly time series, and it is possible to adapt this procedure to convert annual to quarterly series as demonstrated by Abeysinghe and Lee (1998) and Abeysinghe and Rajaguru (2004). In doing so it provides opportunities for using related quarterly series to disaggregate annual data. As data for US and Italian Employment are available quarterly from 1960, it is possible to disaggregate the annual employment series from 1960 into quarterly data using these variables, taking care to match to known annual totals for each country. Therefore, the approach models these available non-stationary cointegrated employment series to produce otherwise unavailable quarterly estimates, ensuring that the annual values of the predicted quarterly data correspond to the observed annual data in each country. However, as noted by the OECD, quarterly employment data does not sum to annual data, it is averaged to annual data. In order to ensure that the employment data averages, as oppose to sums, to equal the annual data, further adjustment to the series is carried out. Where we do have known quarterly series available, we have used these in place of the Chow-Lin based estimates, although the differences between the two are very minor. Further technical details are available on request.

A2. Dickey-Fuller Tests for Full Sample

This appendix presents the diagnostic statistics for the VEC model estimates for the full sample. This ranges from 1960Q1 to 2011Q1. The augmented Dickey-Fuller tests on GDP and employment levels for the six log GDP and employment series for each specific 'target' country, the EU minus the 'target' country, and the US are presented in Table 2. In the case of all countries and EU14 aggregates we do not reject the null of a unit root for levels, but do so for differences, indicating that shocks to levels have a permanent effect, they are I(1) series.

Table A.2: Results of Augmented Dickey Fuller Tests – Full Sample

	US	Ireland	EU14-Ireland	Germany	EU14-Germany	UK
Output - Level	-2.599	-1.485	-1.721	-1.456	-1.929	-2.192
Output - First Differences	-6.571***	-4.431***	-5.247***	-7.394***	-4.592***	-6.145***
Employment - Levels	0.205	-1.770	-1.641	-0.804	-1.650	-2.611
Employment - First Differences	-4.822***	-4.614***	-4.522***	-5.603***	-4.369***	-3.702***

	EU14-UK	France	EU14-France	Italy	EU14-Italy
Output - Level	-1.858	-2.725	-1.554	-1.217	-1.835
Output - First Differences	-5.135***	-6.059***	-5.331***	-5.864***	-5.416***
Employment - Levels	-1.668	-2.300	-1.638	-3.049	-1.708
Employment - First Differences	-4.962***	-5.004 ***	-4.508 ***	-7.038***	-4.188***

Note 1: All Dickey-Fuller tests applied to GDP and employment levels include a constant and trend term. The critical values for Dickey-Fuller tests which include trends are -4.006, -3.437 and -3.137 for the 0.01, 0.05 and 0.1 levels of significance respectively.

2: All Dickey-Fuller tests applied to GDP and employment in first differences include only a constant. The critical values for Dickey-Fuller tests, excluding trends are -3.476, -2.883 and -2.573 for the 0.01, 0.05 and 0.1 levels of significance respectively.

3: All variables are expressed in natural logarithms.

4: ***, ** and * indicate rejection of the null hypothesis at the 0.01, 0.05 and 0.1 level of significance respectively.

5: The null hypothesis is that the data possesses a unit root.

A3. Dickey-Fuller Tests for Sub Period

Table A.3: Results of Augmented Dickey Fuller Tests – Full Sample

	US-Ireland	Ireland	EU14-Ireland	US-Germany	Germany	EU14-Germany
Output - Level	-1.366	-2.642	0.283	-2.806	-1.871	-1.819
Output - First Differences	-4.544***	-4.442***	-3.775***	-5.453***	-6.81***	-4.077***
Employment - Levels	-2.985	-1.993	-2.400	-2.977	-0.299	-1.456
Employment - First Differences	-3.730***	-5.291***	-4.181***	-4.507***	-4.345***	-4.503***

	US-UK	UK	EU14-UK	US-France	France	EU14-France
Output - Level	-2.828	-1.884	-1.753	-2.599	-1.928	-1.627
Output - First Differences	-5.419***	-5.508***	-4.533***	-6.571***	-5.849***	-4.669***
Employment - Levels	-2.170	-1.929	-1.053	-2.941	-1.797	-1.183
Employment - First Differences	-4.599***	-2.770*	-4.939***	-4.554***	-4.269***	-4.274***

	US-Italy	Italy	EU14-Italy
Output - Level	-2.849	-1.689	-1.734
Output - First Differences	-5.481***	-5.462***	-4.825***
Employment - Levels	-2.941	-2.202	-1.828
Employment - First Differences	-4.555***	-6.044***	-3.657***

Note 1: All Dickey-Fuller tests applied to GDP and employment levels include a constant and trend term. The critical values for Dickey-Fuller tests which include trends are -4.006, -3.437 and -3.137 for the 0.01, 0.05 and 0.1 levels of significance respectively.

2: All Dickey-Fuller tests applied to GDP and employment in first differences include only a constant. The critical values for Dickey-Fuller tests, excluding trends are -3.476, -2.883 and -2.573 for the 0.01, 0.05 and 0.1 levels of significance respectively.

3: All variables are expressed in natural logarithms.

4: ***, ** and * indicate rejection of the null hypothesis at the 0.01, 0.05 and 0.1 level of significance respectively.

5: The null hypothesis is that the data possesses a unit root.

A4. SBIC Tests for Appropriate Lag Length

Table A.4: Results of SBIC for Ideal Lag Length – Full Sample

Lag Length	Ireland	Germany	UK	France	Italy
0	-18.827	-22.3703	-22.7322	-25.1242	-23.1711
1	-43.8362	-45.3327	-46.2541*	-46.8068	-45.454
2	-44.0435*	-45.3679*	-46.0292	-46.9223*	-45.5294*
3	-43.4651	-44.8036	-45.3812	-46.4106	-44.8834
4	-42.994	-44.1679	-44.7884	-45.8484	-44.2966

Note 1: The ideal lag length as selected by SBIC is given as the lowest value derived from the various lags.
2: * indicates the ideal lag length.

Table A.5: Results of SBIC for Ideal Lag Length – Sub Periods

Lag Length	Ireland	Germany	UK	France	Italy
0	-27.8889	-25.2874	-26.2392	-28.9839	-25.8788
1	-43.6816	-44.2692	-44.549*	-46.2996*	-43.9249*
2	-44.0362*	-44.745*	-43.7621	-46.0819	-43.7904
3	-42.7584	-43.9037	-42.747	-45.0576	-42.8334
4	-41.718	-43.0457	-41.8429	-44.2193	-41.9265

Note 1: The ideal lag length as selected by SBIC is given as the lowest value derived from the various lags.
2: * indicates the ideal lag length.

A5. Results of the Johansen Cointegration Tests

Table A.6: Results of Johansen's Trace Tests for Cointegration – Full Sample

Time	Ireland		Germany	
r	**Constant**	Restricted Trend	**Constant**	Restricted Trend
0	155.6241	186.4354	94.15	181.8287
1	87.948	116.6207	81.6651	110.1217
2	47.7997	72.9546	48.2338	72.9939
3	**19.5923***	37.8381*	**22.9943***	39.6381*
4	4.5857	13.9452	7.752	19.9041
5	1.0427	2.9466	0.4209	6.4678

	UK		France	
r	Constant	**Restricted Trend**	**Constant**	Restricted Trend
0	328.9186	272.7849	140.4167	175.9147
1	186.1572	127.7704	82.8238	109.6807
2	86.543	65.2663	48.1935	74.382
3	32.3905	**34.0089***	**27.9065***	45.2676
4	11.8507*	15.0622	12.7941	26.0269
5	0.0748	3.3871	0.2717	10.9173*

	Italy	
r	**Constant**	Restricted Trend
0	94.15	104.94
1	93.0449	92.1989
2	58.2097	59.4825
3	30.1078	28.9822
4	**10.4921***	14.9299*
5	0.0034	2.2543

Note 1: * indicates failure to reject the null hypothesis of no more than *r* cointegrating relationships at the 0.05 level of significance.

2: The lag length used in each of the estimations is determined through the use of the SBIC.

3: Bold highlights indicate the rank and model used in the 'optimal' estimation of the VEC model.

Table A.7: Results of Johansen's Trace Tests for Cointegration – Sub Periods

	Ireland		Germany	
r	Constant	**Restricted Trend**	**Constant**	Restricted Trend
0	146.0341	165.0341	122.1625	114.9
1	96.4512	115.093	79.0052	103.3847
2	56.3435	72.0123	**45.0672***	63.4054
3	30.6338	**41.1221***	23.4963	41.5542*
4	16.006	16.121	8.2173	20.8811
5	6.208	6.3199	0.9968	6.3779

	UK		France	
r	**Constant**	Restricted Trend	**Constant**	Restricted Trend
0	178.7014	114.9	234.1767	254.371
1	95.2899	115.5817	125.8346	145.8483
2	56.9138	76.0378	74.9049	94.815
3	**28.9730***	48.0931	40.027	58.6389
4	7.9687	25.47	18.2651	31.513
5	1.2209	6.6621*	**1.5740***	13.2189*

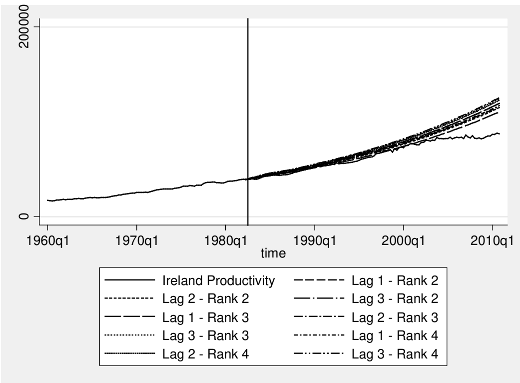
	Italy	
r	**Constant**	Restricted Trend
0	94.15	114.9
1	93.3226	116.9929
2	55.8901	77.1673
3	**22.3803***	42.9151
4	6.1647	20.9014*
5	0.2957	5.5171

Note 1: * indicates failure to reject the null hypothesis of no more than *r* cointegrating relationships at the 0.05 level of significance.
2: The lag length used in each of the estimations is determined through the use of the SBIC.
3: Bold highlights indicate the rank and model used in the 'optimal' estimation of the VEC model.

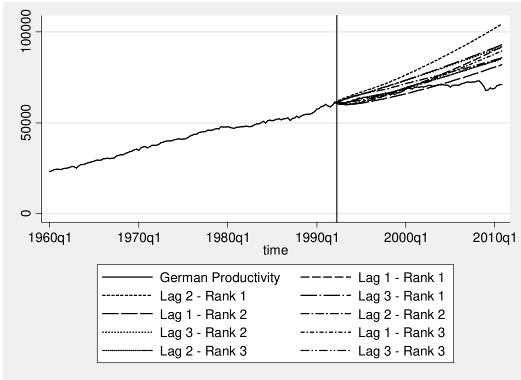
A6. Dynamic Forecasts derived from Alternatively Specified VEC models

Figure A.1: Dynamic Forecasts for Productivity

Ireland



Germany



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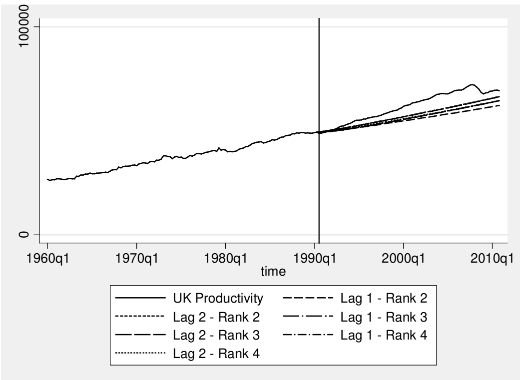
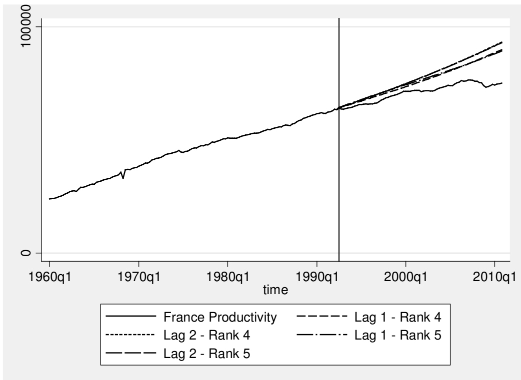


France



Italy

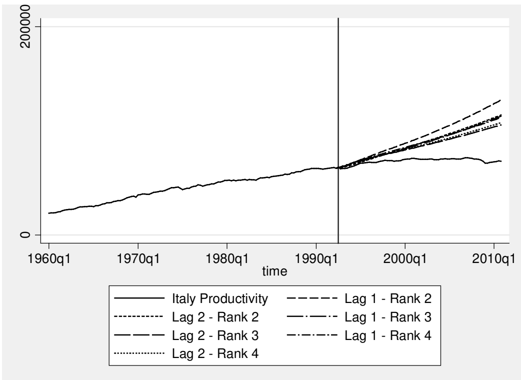


Figure A.2: IRFs based on Alternative VEC models for US GDP -> Productivity

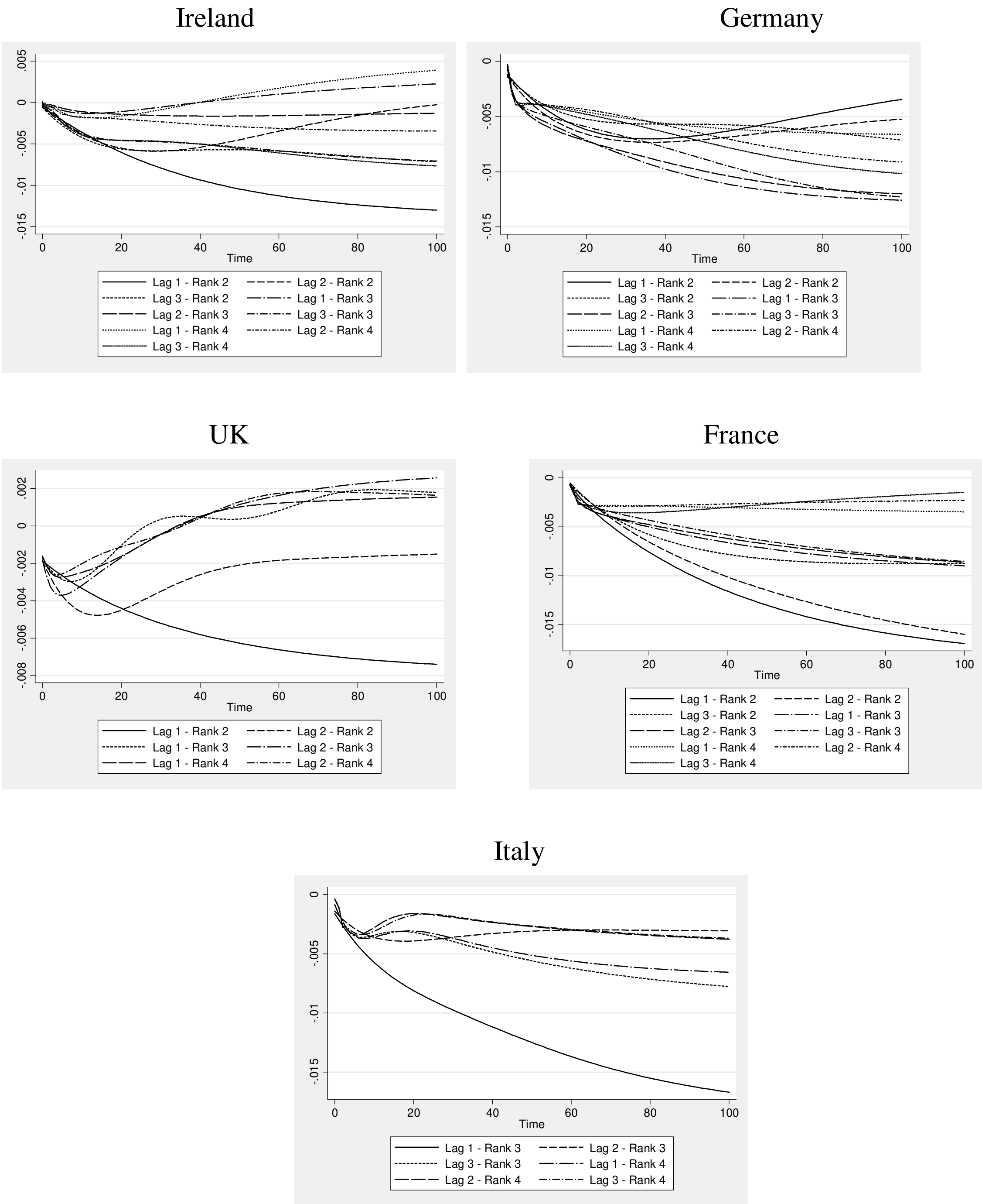
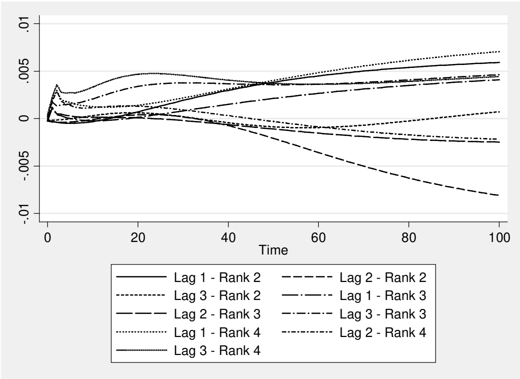
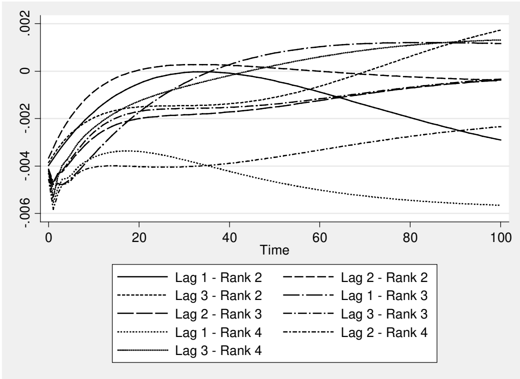


Figure A.3: IRFs based on Alternative VEC models for EU14 GDP -> Productivity

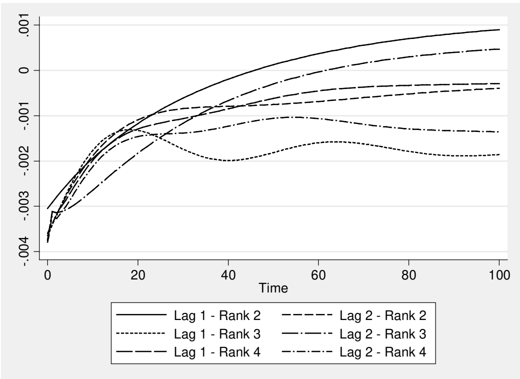
Ireland



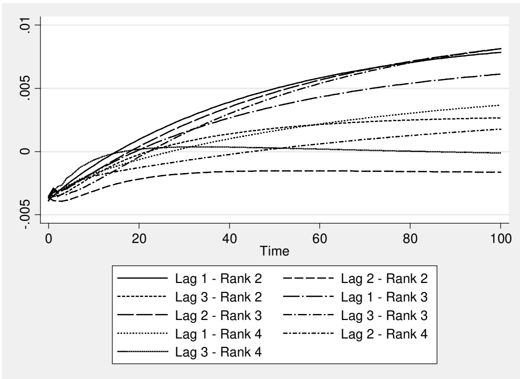
Germany



UK



France



Italy

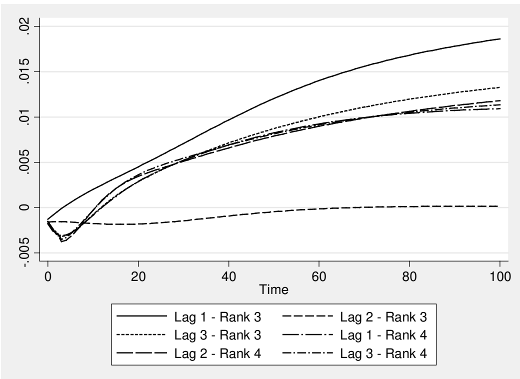
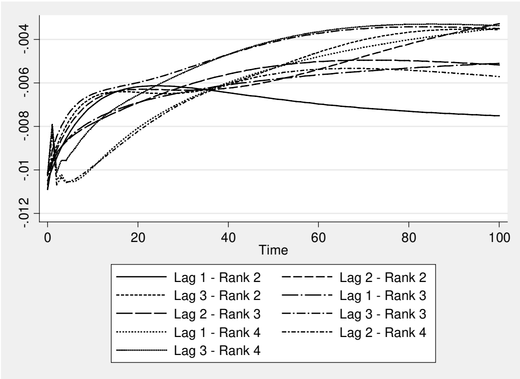
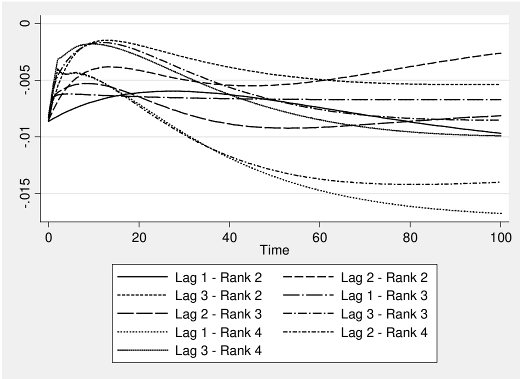


Figure A.4: IRFs based on Alternative VEC models for Domestic GDP -> Productivity

Ireland



Germany



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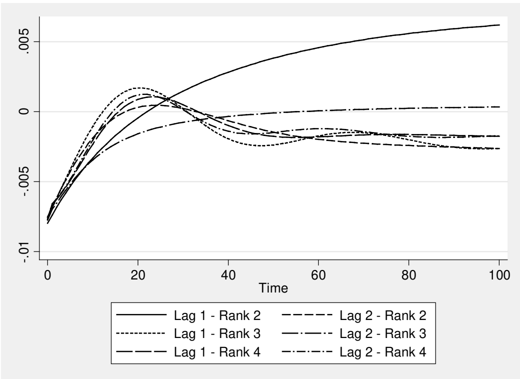
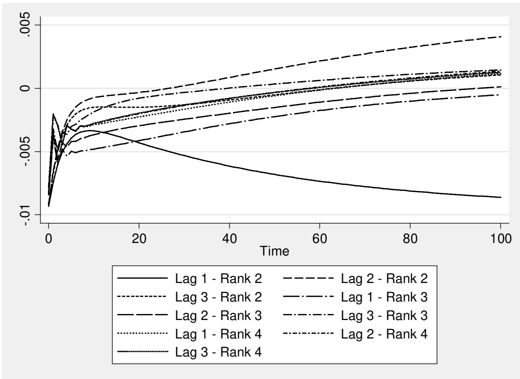
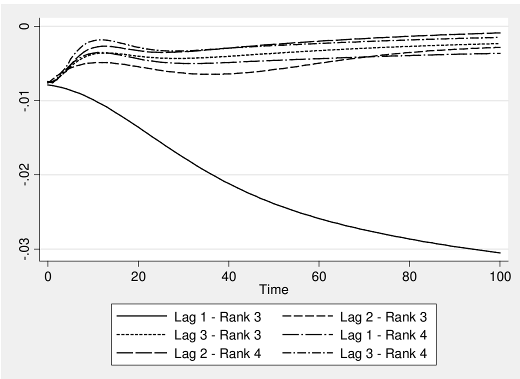


France



Italy



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