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FOREIGN TRADE, HOME LINKAGES AND THE SPATIAL TRANSMISSION OF ECONOMIC FLUCTUATIONS IN ITALY

by Valter Di Giacinto*

Abstract

During the recent global recession both the export-oriented northern Italian regions and those in the far less open South experienced a sharp decline in economic activity. One of the possible explanations is the existence of strong domestic linkages propagating foreign demand shocks from North to South. To assess the scope of the spatial transmission of global and local disturbances across Italian regions, in this paper we specify and estimate a bivariate structural spatial VAR model featuring GDP and foreign exports as endogenous variables. A standard gravity equation approach is implemented to model unobserved domestic regional trade flows, while regional sales on foreign markets are related to global trade fluctuations and local shocks to competitiveness, broken down into a national and an idiosyncratic component. In line with expectations, strong domestic linkages are uncovered on the basis of model estimation results. The latter show that even less export-oriented Italian regions, although broadly unaffected on impact, may eventually experience a sharp output decline following a fall in global trade of the size observed in the recent recession.

JEL Classification: C21, C33, F14.
Keywords: panel VAR model, trade linkages, spatial econometrics.

Contents

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1. Introduction[1]

Even within countries with a high degree of integration in global markets, regional economies can have large differences as regards the impact of foreign trade on gross domestic product.

When large exogenous shocks to international trade occur, as in the case of the recent global recession, it is expected that regional economies that are less dependent on foreign demand will be affected to a lesser extent. However, this consideration ignores the possibility that shocks to foreign economies affect regional output growth via trade linkages on the domestic market.

Indeed, albeit featuring a far lower degree of foreign openness, in the aftermath of the global financial crisis southern Italian regions have undergone a recession almost as bad as the one incurred by the export-oriented industrial areas in the North.

There are a number of alternative explanations for this:

- regional economies may have different elasticities of exports in respect of global demand shocks or different export/GDP ratios, possibly reflecting heterogeneous patterns of industrial specialization or other underlying structural factors;
- strong trade linkages in the domestic market may propagate global shocks to less open regional economies;
- other channels of spatial transmission of global disturbances, unrelated to bilateral trade flows, may be operating, as is the case of the mechanisms propagating contagion via financial markets and intermediaries.

By properly controlling for cross-sectional heterogeneity in the elasticity of exports to foreign demand shocks and of local output to exports, the methodology employed in this paper focuses on the role of trade linkages in propagating global and local demand shocks within the country. In order to identify local demand disturbances better, some allowance is made for the existence of supply-side disturbances affecting the competitiveness of local producers. A process of spatial diffusion of supply-side shocks due to knowledge spillovers across regions is also allowed for. However, the analysis of alternative channels of transmission, namely financial relations, is ruled out at the present stage and is left for future investigation.

From an empirical viewpoint, a number of recent studies analysing macroeconomic interdependencies implied by both direct and indirect trade linkages have relied on structural vector autoregressive (VAR) models. Multi-area VAR models, once properly identified and estimated, allow in fact for a straightforward assessment of the dynamic propagation of a shock originating in a given economy to the related countries' GDP.

Examples of this approach include Abeysinghe and Forbes (2005), who use trade linkages to estimate the multiplier effects as a shock is transmitted through output fluctuations across trade partner countries, introducing a new specification strategy that reduces the number of unknowns in the VAR (the "AF" model). It is fitted to 11 Asian countries, the US, and the rest of the OECD, showing that multiplier effects are large and

[1] I would like to thank Andrea Silvestrini and two anonymous referees for their useful comments and suggestions. The views expressed are my own and do not necessarily reflect those of the Bank of Italy.

can transmit shocks in very different patterns from those predicted on the basis of a bilateral trade matrix.

Ohyama (2004), extends the AF model by incorporating the influence of changes in trade openness and country specific input-good prices. In this case too, a series of impulse response analyses indicate an important transmission channel across countries, namely the output-multiplier effect, that has been overlooked in models using only bilateral trade relationships.

Building further on the work of Abeysinghe and Forbes, Korhonen and Ledyaeva (2008), assess the impact of oil price shocks on oil-producer and oil-consumer economies, linking together VAR models for different countries in a trade matrix.

In a more general modelling environment, allowing for the identification of different sources of economic disturbances at both the national and international level, global VAR (GVAR) models (Pesaran et al., 2004) provide a different approach to the transmission of macroeconomic fluctuations across countries.

The specification of multi-country VAR models usually relies on the direct observability of data on bilateral trade flows to derive a set of parametric restrictions that make the simultaneous treatment of a large number of countries feasible.

The major difficulty hindering the direct implementation of this approach to the case of multiple regions within a single country lies in the general unavailability of statistics on bilateral domestic trade flows. As a consequence, there is only limited empirical evidence on the extent of inter-regional trade linkages, a recent exception being Pavia et al. (2006), whose empirical methodology relies however on multi-regional input-output analysis rather than structural vector autoregressions.

In this paper, the AF approach is extended and implemented in a multi-regional environment featuring both multilateral regional trade linkages in the domestic market and export flows to the rest of the world. The empirical specification entails a bivariate multi-regional VAR model featuring GDP and export growth as endogenous variables and two macro indicators (global trade flows and export competitiveness at the national level) as exogenous sources of common disturbances.

From a methodological viewpoint, by referring to the usual gravity equation approach, unobserved domestic trade flows across regions are modelled as a direct function of the size of the local markets and an inverse function of distance in space, plus a random irregular term.

At the same time, regional foreign exports are related to global demand fluctuations and local shocks to competitiveness, broken down into a national and an idiosyncratic component.

These hypotheses, together with the identifying restriction requiring local output shocks to affect regional competitiveness with at least a one period lag, is shown to yield a bivariate structural spatial VAR (SpVAR) specification featuring a block recursive identification scheme in line with the one recently proposed in Di Giacinto (2010).

By properly controlling for the possible heterogeneous influence of common macroeconomic shocks on regional exports and GDP, the proposed structural VAR specification allows us to identify two orthogonal sets of idiosyncratic disturbances − that can be broadly interpreted as structural shocks to local aggregate demand and supply conditions − and the analysis of their dynamic propagation across regions.

The remainder of the paper is organized as follows. The structural SpVAR specification is explained in Section 2, focusing on the exports equation first and then deriving the output equation. Parameter estimation is dealt with in Section 3. Under the assumption that a sufficient number of observations is collected over time, estimation is based on the Full Information Maximum Likelihood (FIML) method, a standard choice in structural VAR modelling. The topic of impulse response analysis is then dealt with in

Section 4. The approach set forth in Di Giacinto (2010) is adapted to the present specification, yielding a synthetic space-time impulse response (STIR) function as a convenient tool to summarize the information conveyed by individual regional dynamic multipliers. In Section 5 the model specified along the lines given in Section 2 is finally fitted to time series for the 20 NUTS 2 Italian regions covering a time span of about 40 years. Based on estimation results, the scope of the spatial propagation of local and global shocks across the Italian territory is subsequently analysed and the extent of spatial spillover effects through internal linkages is assessed. Section 6 summarizes and concludes the paper.

2. The structural spatial VAR model

A bivariate multiregional VAR model is described in this section. Two endogenous variables are considered: exports (sales from a given region to foreign countries) and GDP, their spatio-temporal evolution being modelled as the result of the dynamic propagation of common and idiosyncratic shocks affecting aggregate demand and supply conditions. The main channel of the spatial propagation of economic fluctuations operates, as in AF, via inter-regional trade linkages. However, in line with the predictions of the rich literature on regional science and urban economics, the spatial transmission of supply side shocks due to information spillovers is allowed for as well.

In what follows it is assumed that a bivariate random vector is observed at regular time intervals over a set of N mutually interacting regional economies, with components y_{it} and x_{it} respectively denoting the GDP and foreign exports series recorded on the i-th region (i=1,2,...,N) on time period t=1,2,...,T.

2.1 Export equation

For convenience of exposition, the export equation is specified first, starting from the identity expressing local exports as the product of global demand (D) – assumed to be exogenous under the usual small open country hypothesis – times the local market share:

$$x_{it} = D_t s_{it} \qquad , i=1,2,...,N. \tag{1}$$

Without loss of generality, the regional foreign market share can be decomposed in the contributions of a common national export competitiveness component (η) and of a residual component. By assuming a multiplicative structure, we set

$$s_{it} = \eta_t^{\mu_i} c_{it}, \qquad i=1,2,...,N. \tag{2}$$

Substituting in (1) and taking log differences yields

$$\Delta \log(x_{it}) = \Delta \log(D_t) + \mu_i \Delta \log(\eta_t) + \Delta \log(c_{it}). \tag{3}$$

Since the unobservable local component c_{it} of the export share s_{it} can be correlated with the other two variables on the R.H.S. of (3), it is useful to the decompose it as

$$\Delta \log(c_{it}) = p_{0i} + p_{1i}\Delta \log(D_t) + p_{2i}\Delta \log(\eta_t) + \upsilon_{it} \tag{4}$$

where $\{p_{0i}; p_{1i}; p_{2i}\}$ represent the coefficient of the orthogonal projection of $\Delta \log(c_{it})$ on the vector $\{1; \Delta \log(D_t); \Delta \log(\eta_t)\}$ and υ_{it} is a residual term that is uncorrelated to macro factors by construction. Upon substitution of the above expression in (3), we get the following equation for the local export growth rate

$$\Delta \log(x_{it}) = \alpha_{0i} + \alpha_{1i}\Delta \log(D_t) + \alpha_{2i}\Delta \log(\eta_t) + \upsilon_{it} \tag{5}$$

with $\alpha_{0i} = p_{0i}$, $\alpha_{1i} = (1 + p_{1i})$ and $\alpha_{2i} = (\alpha_i + p_{2i})$.

Considering that υ_{it} can be correlated both over time and across regions, it still cannot be deemed to represent a purely idiosyncratic shock to the competitiveness of local producers on foreign markets. To identify the idiosyncratic component in the growth rate of local competitiveness, υ_{it} is thus subsequently decomposed in the sum of a systematic part, that is assumed to be a linear function of past GDP and export growth in the *i*-th region and in contiguous areas and of current export growth in contiguous regions, and an idiosyncratic random shock, yielding

$$\upsilon_{it} = \sum_{h=0}^{P}\sum_{m=0}^{K} \lambda_{ihm} L^{(m)} \Delta \log(x_{it-h}) + \sum_{h=1}^{P}\sum_{m=0}^{K} \phi_{ihm} L^{(m)} \Delta \log(y_{it-h}) + e_{it} \tag{6}$$

where $\lambda_{i00} \equiv 0$, $E(e_{it}) = 0$, $E(e_{it}e_{it-h}) = \omega_i \delta_{h0}$, δ denoting the Kronecker's delta function ($\delta_{hk} = 1$ if h=k and $\delta_{hk} = 0$ elsewhere), and where $L^{(m)}$ denotes the usual spatial lag operator of order *m* (see, e.g. Anselin and Smirnov, 1996), as defined by the relation

$$L^{(m)} z_{it} = \sum_j w_{ij}^{(m)} z_{ijt} \qquad , i=1,2,\ldots,N \tag{7}$$

$w_{ij}^{(m)}$ denoting the element on the *i*-th row and *j*-th column of the *N*x*N* spatial weights matrix $W^{(m)}$. Spatial lags are usually defined on the basis of a hierarchical ordering of locations according to a measure of distance or general accessibility. As a consequence, the degree of spatial proximity of locations decreases as the order of the spatial lag operator increases.

By referring to the large body of literature on endogenous growth and agglomeration, the rationale for relating local competitiveness growth to past macroeconomic performance in the region and in closely located areas can be traced back to the existence of dynamic MAR (Marshall-Arrow-Romer) externalities, promoting TFP growth within a given region and across contiguous regions via information spillovers (for a review of the large literature on knowledge externalities see, for example, Van Oort, 2004).

Combining (5) and (6) the following final expression for the export equation ensues

$$\Delta\log(x_{it}) = \alpha_{0i} + \alpha_{1i}\Delta\log(D_t) + \alpha_{2i}\Delta\log(\eta_t) + \sum_{h=1}^{P}\sum_{m=0}^{K}\phi_{ihm}L^{(m)}\Delta\log(y_{it-h}) + \\ + \sum_{h=0}^{P}\sum_{m=0}^{K}\lambda_{ihm}L^{(m)}\Delta\log(x_{it-h}) + e_{it}. \tag{8}$$

2.2 Output equation

In deriving the GDP equation, following the AF approach, the starting point is provided by the basic identity of local supply and demand, where demand is broken down into the foreign and domestic components

$$y_{it} = x_{it} + a_{it} \qquad , i=1,2,...,N \tag{9}$$

a_{it} denoting domestic demand net of imports. In terms of growth rates the identity becomes

$$\Delta\log(y_{it}) = s_{it-1}\Delta\log(x_{it}) + (1 - s_{it-1})\Delta\log(a_{it}) \tag{10}$$

where the two terms on the R.H.S. give the contributions of foreign and internal demand to output growth and where $s_{it} = x_{it} / y_{it}$ is the export share of GDP.

If data on inter-regional trade flows on the domestic market were available, the growth rate of internal sales could be readily broken down into its individual regional contributions. With trade data available we would have the following identity

$$\Delta\log(a_{it}) = \sum_{j=1}^{N} q_{ijt-1}\Delta\log(a_{ijt}) \tag{11}$$

where $q_{ijt} = a_{ijt} / a_{it}$, a_{ijt} denoting output produced in region *i* and sold in region *j*. Since a_{ijt} is not observed, the chosen specification strategy assumes that trade flows a_{ijt}, (*i*,*j*=1,…,*N*), can be predicted by means of a gravity model.

The gravity equation approach provides a reference methodology in the analysis of international trade flows and, in his much cited article on trade patterns across Canadian provinces and US states, McCallum (1995) showed how the approach performed equally well within country borders. Building on this evidence, we derive the missing inter-regional trade flows by assuming that a similar trade pattern holds for the set of regions considered here.

In the gravity approach to trade, sales from region *i* to region *j* are directly related to the level of GDP in both the home and the destination market and inversely related to a power law function of the distance separating the two regions. Under these assumptions we can write

$$\overline{a}_{ijt} = d_{ij}^{-\delta} y_{it}^{\beta_{1i}} y_{jt}^{\beta_{2i}} \tag{11}$$

Which, upon taking logarithmic differences, yields

$$\Delta \log(\overline{a}_{ijt}) = \beta_{1i} \Delta \log(y_{it}) + \beta_{2i} \Delta \log(y_{jt}). \tag{12}$$

At this stage, we introduce the assumption that the actual growth rate of domestic trade flows is equal to the value predicted by the gravity model plus a random stochastic term and importer-exporter fixed effects. The latter, following Anderson and van Wincoop (2003) and Feenstra (2002), are included to control for multilateral resistance terms, measuring the "remoteness" of individual regions with respect to the whole set of trading partners, and other possibly omitted factors that are constant across time but vary across regions. Under this assumption we obtain

$$\Delta \log(a_{ijt}) = \Delta \log(\overline{a}_{ijt}) + \beta_{0i} + \mu_{0j} + u_{ijt} \tag{13}$$

where $E(u_{ijt}) = 0$, $E(u_{ijt} u_{ijt-h}) = \sigma^2 \delta_{h0}$ $(i,j=1,\ldots,N)$. Considering jointly equations (11)-(13), the growth rate of aggregate domestic sales for region i can be expressed as

$$\Delta \log(a_{it}) = \beta_{0i} + \sum_{j=1}^{N} q_{ijt-1} \mu_{0j} + \beta_{1i} \Delta \log(y_{it}) + \beta_{21i} \sum_{j=1}^{N} q_{ijt-1} \Delta \log(y_{jt}) + u_{it} \tag{14}$$

where $u_{it} = \sum_{j=1}^{N} q_{ijt-1} u_{ijt}$, $E(u_{it}) = 0$, $E(u_{it} u_{it-h}) = \sigma^2 \sum_{j=1}^{N} q_{ijt-1}^2 \delta_{h0}$, the composite disturbance term u_{it} being expressed as a linear combination, weighted by domestic trade shares, of the random shocks affecting bilateral trade flows between the i-th region and the whole set of regions in the sample (including region i itself).

To make equation (14) operational for estimating purposes, the problem of the unobservability of domestic trade shares q_{ijt} has to be dealt with. To this end, considering that in a range of potential empirical applications the shares can be taken to be more or less constant over the sample period, as they represent slowly evolving features of the set of local economies, expression (14) can be simplified by imposing fixed values for q_{ijt}, yielding the following more tractable specification

$$\Delta \log(a_{it}) = \overline{\beta}_{0i} + \beta_{1i} \Delta \log(y_{it}) + \beta_{1i} \sum_{j=1}^{N} q_{ij} \Delta \log(y_{jt}) + u_{it} \tag{15}$$

where $\overline{\beta}_{0i} = \beta_{0i} + \sum_{j=1}^{N} q_{ij} \mu_{0j}$ and $E(u_{it} u_{it-h}) = \sigma^2 \sum_{j=1}^{N} q_{ij}^2 \delta_{h0} = \psi_i \delta_{h0}$.

At this stage, by referring again to the gravity approach, it is assumed that domestic trade shares can be approximated on the basis of trade flows predicted by the gravity model, i.e. we set

$$q_{ijt} \cong \overline{a}_{ijt} / \Sigma_j \overline{a}_{ijt} = d_{ij}^{-\delta} y_{jt}^{\beta_{2i}} / \Sigma_j d_{ij}^{-\delta} y_{jt}^{\beta_{2i}} . \tag{16}$$

A further convenient simplification can now be introduced by assuming unit output elasticity of trade. In this case, expression (16) can be simply related to regional GDP shares in the following way

$$q_{ijt} \cong d_{ij}^{-\delta} \widetilde{y}_{jt} / \Sigma_j d_{ij}^{-\delta} \widetilde{y}_{jt} = w_{ij}^{*} \tag{17}$$

where $\widetilde{y}_{jt} = y_{jt} / y_t$. Assuming that GDP shares are constant over time yields the following expression

$$q_{ij} \cong d_{ij}^{-\delta} \widetilde{y}_j / \Sigma_j d_{ij}^{-\delta} \widetilde{y}_j = w_{ij}^{*} \tag{18}$$

that, upon substitution in (14), finally yields

$$\Delta \log(a_{it}) = \overline{\beta}_{0i} + \beta_{1i} \Delta \log(y_{it}) + \beta_{2i} \sum_{j=1}^{N} w_{ij}^{*} \Delta \log(y_{jt}) + u_{it}. \tag{19}$$

The shocks u_{ijt} to sales from region i to region j can be deemed to reflect the influence of both demand shocks originating on the j-th regional market and supply disturbances affecting the domestic trade competitiveness of producers located within the i-th region. Assuming that idiosyncratic productivity shocks fostering competitiveness on foreign markets also affect competitiveness on the domestic markets, the composite disturbance term in (17) can be decomposed in the following way

$$u_{it} = \kappa e_{it} + v_{it} \tag{20}$$

where κ is the coefficient of the linear projection of u_{it} on e_{it} and where v_{it} is a residual stochastic component, with $E(v_{it}) = 0$ and $E(v_{it} v_{jt-h}) = \tau_i \delta_{h0} \delta_{ij}$, that is orthogonal to e_{it} by construction.

To the extent that only one source of local supply disturbances drives regional competitiveness on both foreign and domestic markets, the structural error v_{it} can be interpreted as a composite demand shock on the domestic market, combining shocks occurring in individual regional markets according to their relative importance (measured by bilateral trade shares) for producers located in the i-th region.

Substituting expressions (19) and (20) in the GDP equation subsequently yields

$$\begin{aligned} \Delta \log(y_{it}) = s_{it-1} \Delta \log(x_{it}) + (1 - s_{it-1}) \overline{\beta}_{0i} + (1 - s_{it-1}) \beta_{1i} \Delta \log(y_{it}) + \\ + (1 - s_{it-1}) \beta_{2i} \sum_{j=1}^{N} w_{ij}^{*} \Delta \log(y_{jt}) + (1 - s_{it-1})(\kappa e_{it} + v_{it}). \end{aligned} \tag{21}$$

Considering that local GDP growth is included also on the R.H.S. of equation (21) the equation does not turn out to be properly normalized. To achieve normalization, noting that

$$\sum_{j=1}^{N} w_{ij}^{*}\Delta\log(y_{jt}) = w_{ii}^{*}\Delta\log(y_{it}) + \sum_{j\neq i} w_{ij}^{*}\Delta\log(y_{jt}) \tag{22}$$

where $w_{ii}^{*} \neq 0$ because of the existence of within region trade flows, we can immediately normalize the equation with respect to $\Delta\log(y_{it})$, yielding

$$\begin{aligned}\Delta\log(y_{it}) = r_{it-1}[&s_{it-1}\Delta\log(x_{it}) + (1-s_{it-1})\overline{\beta}_{0i} \\ &+ (1-s_{it-1})\beta_{1i}L^{*}\Delta\log(y_{it}) + (1-s_{it-1})(\kappa e_{it} + v_{it})]\end{aligned} \tag{23}$$

where the following positions have been made

$$\begin{aligned} L^{*}\Delta\log(y_{it}) &= \sum_{j\neq i} w_{ij}^{*}\Delta\log(y_{jt}) \\ r_{it} &= [1-(1-s_{it})(\beta_{1i} + \beta_{2i}w_{ii}^{*})]^{-1}\end{aligned} \tag{24}$$

and where L^{*} denotes, as above, the spatial lag operator obtained for the specific definition of the spatial weights given by expression (18).

The presence of time varying export shares in (21), even if they are observable quantities, makes the equation unwieldy for the purposes of empirical estimation. Since such shares typically reflect the structural features of the local economies that evolve slowly over time, in what follows they will be treated as fixed unknown constants, whose values are subsumed within model parameters. Considering this approximation, the GDP equation becomes

$$\Delta\log(y_{it}) = \chi_i\Delta\log(x_{it}) + \widetilde{\beta}_{0i} + \widetilde{\beta}_{2i}\Delta L^{*}\log(y_{ijt}) + \widetilde{\kappa}_i e_{it} + \zeta_{it} \tag{25}$$

where $\chi_i = r_i s_i$, with $r_i = [1-(1-s_{it})(\beta_{1i} + \beta_{2i}w_{ii}^{*})]^{-1}$, $\widetilde{\beta}_{0i} = r_i(1-s_i)\overline{\beta}_{0i}$, $\widetilde{\beta}_{2i} = r_i(1-s_i)\beta_{2i}$, $\widetilde{\kappa}_i = r_i(1-s_i)\kappa$ and $\zeta_{it} = r_i(1-s_i)v_{it}$.

From the export equation, the following expression for e_{it} can be derived

$$\begin{aligned} e_{it} = \Delta\log(x_{it}) - \alpha_{0i} - \alpha_{1i}\Delta\log(D_t) - \alpha_{2i}\Delta\log(\eta_t) - \alpha_i\Delta\log(\eta_t) + \\ -\sum_{h=1}^{P}\sum_{m=0}^{K}\phi_{ihm}L^{(m)}\Delta\log(y_{it-h}) - \sum_{h=0}^{P}\sum_{m=0}^{K}\lambda_{ihm}L^{(m)}\Delta\log(x_{it-h})\end{aligned} \tag{26}$$

which, once substituted in expression (25), yields (after a final reparametrization) the following estimating equation for local GDP growth

$$\begin{aligned}\Delta\log(y_{it}) = \rho_{0i} + \rho_{1i}\Delta\log(D_t) + \rho_{2i}\Delta\log(\eta_t) + \widetilde{\beta}_{2i}\Delta L^{*}\log(y_{ijt}) \\ +\sum_{h=1}^{P}\sum_{m=0}^{K}\pi_{ihm}L^{(m)}\Delta\log(y_{it-h}) + \sum_{h=0}^{P}\sum_{m=0}^{K}\gamma_{ihm}L^{(m)}\Delta\log(x_{it-h}) + \zeta_{it}\end{aligned} \tag{27}$$

where $\rho_{0i} = \tilde{\beta}_{0i} - \tilde{\kappa}_i \alpha_{0i}$, $\rho_{hi} = -\tilde{\kappa}_i \alpha_{hi}$ $(h \in \{1,2\})$, $\pi_{ihk} = -\tilde{\kappa}_i \lambda_{ihm}$, $\gamma_{ihk} = \chi_i \delta_{h0} \delta_{k0} - \tilde{\kappa}_i \lambda_{ihm}$, h=0,1,…,P, m=0,1,…K and where the disturbance term has a zero mean and covariance function $E(\zeta_{it}\zeta_{jt-h}) = \vartheta_i \delta_{h0} \delta_{ij}$ (i,j=1,…,N).

Expressions (8) and (27) jointly define a structural spatial VAR (SpVAR) model, as recently defined in Beenstock and Felsenstein (2007) and Di Giacinto (2010). In line with the approach set forth in the latter, the identification scheme involves a block recursive structure, which is achieved in this case because the error terms in the exports and GDP equations are orthogonal by construction and, at the same time, while current shocks to export growth immediately affect GDP growth, the opposite situation does not hold, local competitiveness being influenced by GDP growth at least with a one period lag (recursiveness assumption).

Stacking observations on the N spatial units, the model can be given the following vector expression

$$\mathbf{C}_0 \mathbf{z}_t = \mathbf{G}\Xi_t + \mathbf{C}_1 \mathbf{z}_{t-1} + ... + \mathbf{C}_p \mathbf{z}_{t-p} + \varepsilon_t \tag{28}$$

where

$\Xi_t = [\iota'_N D_t, \iota'_N \eta_t]'$, $\mathbf{G} = \begin{bmatrix} \iota_N & \alpha \\ \rho_2 & \rho_3 \end{bmatrix}$ (ι_N denoting an N-dimensional vector with all elements equal to one)

$$\alpha = [\alpha_1,...,\alpha_N]', \ \rho_2 = [\rho_{21},...,\rho_{2N}]', \ \rho_3 = [\rho_{31},...,\rho_{3N}]'$$

$$\mathbf{z}_t = [\mathbf{x}'_t, \mathbf{y}'_t]', \ \mathbf{x}_t = [\Delta\log(x_{1t}),...,\Delta\log(x_{Nt})]', \ \mathbf{y}_t = [\Delta\log(y_{1t}),...,\Delta\log(y_{Nt})]',$$

$$\varepsilon_t = [\mathbf{e}'_t, \zeta'_t]', \ e_t = [e_{1t},...,e_{Nt}]', \ \zeta_t = [\zeta_{1t},...,\zeta_{Nt}]'$$

$$E(\varepsilon\varepsilon') = \Omega = diag\{[\omega_1,....,\omega_N,\vartheta_1,....,\vartheta_N]\}$$

$$\mathbf{C}_0 = \begin{bmatrix} \mathbf{A}_{11}^{(0)} & 0 \\ \mathbf{A}_{21}^{(0)} & \mathbf{A}_{22}^{(0)} \end{bmatrix} \tag{29}$$

$$\mathbf{C}_h = \begin{bmatrix} \mathbf{A}_{11}^{(h)} & \mathbf{A}_{12}^{(h)} \\ \mathbf{A}_{21}^{(h)} & \mathbf{A}_{22}^{(h)} \end{bmatrix} \tag{30}$$

$$h=1,...,P$$

and where the following positions have been made

$$\mathbf{A}_{11}^{(0)} = \mathbf{I}_N - \sum_{m=1}^{K} \Lambda_{0m} \mathbf{W}^{(m)}, \ \mathbf{A}_{21}^{(0)} = \sum_{m=0}^{K} \Gamma_{0m} \mathbf{W}^{(m)}, \ \mathbf{A}_{22}^{(0)} = \mathbf{I}_N - \sum_{m=1}^{K} \mathbf{B}\mathbf{W}^{*}$$

$$\mathbf{A}_{11}^{(h)} = \sum_{m=0}^{K} \Lambda_{hm} \mathbf{W}^{(m)}, \ \mathbf{A}_{12}^{(h)} = \sum_{m=1}^{K} \Phi_{hm} \mathbf{W}^{(m)}, \ \mathbf{A}_{21}^{(h)} = \sum_{m=0}^{K} \Gamma_{hm} \mathbf{W}^{(m)}, \ \mathbf{A}_{22}^{(h)} = \sum_{m=0}^{K} \Pi_{0m} \mathbf{W}^{(m)},$$

$$h=1,\ldots,P$$

$$\mathbf{W}^{(0)} = \mathbf{I}_N$$

$$\mathbf{B} = diag\{[\tilde{\beta}_{21},...,\tilde{\beta}_{2N}]\}$$

$$\Lambda_{hm} = diag\{[\lambda_{1hm},...,\lambda_{Nhm}]\}, \ \Phi_{hm} = diag\{[\phi_{1hm},...,\phi_{Nhm}]\}$$

$$\Gamma_{hm} = diag\{[\gamma_{1hm},...,\gamma_{Nhm}]\}\,,\ \Pi_{hm} = diag\{[\pi_{1hm},...,\pi_{Nhm}]\}$$

$$h=0,1,\ldots,P \quad m=0,1,\ldots,K.$$

From expression (28) it can be noted that the SpVAR model is formally equivalent to a standard structural VAR model with $2N$ equations. However, in this case coefficients matrices involve a number of constraints deriving from the specification of spatial interactions by means of a sequence of spatial weights matrices.

Provided matrix $\boldsymbol{C}_0$ is invertible, a condition that can always be achieved by placing some restrictions on the admissible values of VAR coefficients, the reduced form expression of the SpVAR model can be defined in the usual way, by setting

$$\mathbf{z}_t = \widetilde{\mathbf{G}}\Xi_t + \widetilde{\mathbf{C}}_1\mathbf{z}_{t-1} + ... + \widetilde{\mathbf{C}}_p\mathbf{z}_{t-p} + \widetilde{\boldsymbol{\varepsilon}}_t \tag{31}$$

with $\widetilde{\mathbf{G}} = \mathbf{C}_0^{-1}\mathbf{G}$, $\widetilde{\boldsymbol{C}}_h = \boldsymbol{C}_0^{-1}\boldsymbol{C}_h$, h=1,...,p, and $\widetilde{\boldsymbol{\varepsilon}}_t = \boldsymbol{C}_0^{-1}\boldsymbol{\varepsilon}_t$.

The reduced form can then be utilized, as in the standard VAR case, to compute forecasts on the basis of the conditional expectations given by

$$E[\mathbf{z}_{t|t-1}] = \widetilde{\mathbf{G}}\Xi_t + \widetilde{\mathbf{C}}_1\mathbf{z}_{t-1} + ... + \widetilde{\mathbf{C}}_p\mathbf{z}_{t-p}\,. \tag{32}$$

or to check for stability, by computing the roots of the characteristic equation.

3. Maximum likelihood estimation

Assuming that sufficiently long time series are available, inference on model parameters can be fruitfully based on the methods usually employed in multiple time series analysis, like maximum likelihood (ML).In particular, following a standard approach in the structural VAR literature, in this section consistent estimators of model parameters will be derived by applying the FIML method (Full Information Maximum Likelihood: Hamilton, 1994, Chapter 11; Amisano and Giannini, 1997), which appears to be well suited to deal with a specification involving both a $\mathbf{C}_0$ matrix that is not strictly triangular (as is the case when the SpVAR specification includes simultaneous spatial interaction terms) and a set of parameter constraints on the $\mathbf{C}_h$ matrices (h>0) and the error covariance matrix Ω.

Under the assumption of joint normality, the distribution of $\mathbf{z}_t$, conditional on past observations $\mathbf{z}_{t-1}$, $\mathbf{z}_{t-2}$,..., will be Gaussian with mean

$$E[\mathbf{z}_{t|t-1}] = \hat{\mathbf{z}}_t = \widetilde{\mathbf{G}}\Xi_t + \widetilde{\mathbf{C}}_1\mathbf{z}_{t-1} + ... + \widetilde{\mathbf{C}}_p\mathbf{z}_{t-p}$$

and covariance matrix $\widetilde{\Omega} = E[\widetilde{\boldsymbol{\varepsilon}}_t\widetilde{\boldsymbol{\varepsilon}}_t'] = (\mathbf{C}_0^{-1})\Omega(\mathbf{C}_0^{-1})'$.

The log of the conditional distribution will hence have the expression

$$\begin{aligned}\log f(\mathbf{z}_t \mid \mathbf{z}_{t-1}, \mathbf{z}_{t-2}, ...) &= const. - \frac{1}{2}\log(|\widetilde{\Omega}|) - \frac{1}{2}(\mathbf{z}_t - \hat{\mathbf{z}}_t)'\widetilde{\Omega}^{-1}(\mathbf{z}_t - \hat{\mathbf{z}}_t) = \\ &= const. + \log(|\mathbf{C}_0|) - \frac{1}{2}\log(|\Omega|) - \frac{1}{2}\varepsilon_t'\Omega^{-1}\varepsilon_t\end{aligned} \tag{33}$$

where $\varepsilon_t = \mathbf{C}_0\mathbf{z}_t - \mathbf{G}\Xi_t - \mathbf{z}_{t-1} - ... - \mathbf{z}_{t-p}$.

Given the block triangular structure of $\mathbf{C}_0$ it follows that $|\mathbf{C}_0| = \prod_{r=1}^{K} |\mathbf{A}_{rr}^0|$ and the log of the sample distribution of $\mathbf{z}_t$, conditional on p pre-sample values and assuming T consecutive observations are collected over time, will hence have the expression

$$\begin{aligned}
&\log f(\boldsymbol{y}_1, \boldsymbol{y}_2, ..., \boldsymbol{y}_T \mid \boldsymbol{y}_0, \boldsymbol{y}_{-1}, ..., \boldsymbol{y}_{-p+1}) = \\
&= c + T\log(|\mathbf{C}_0|) - \frac{T}{2}\log(|\Omega|) - \frac{1}{2}\sum_{t=1}^{T}\boldsymbol{\varepsilon_t}'\Omega^{-1}\boldsymbol{\varepsilon_t} \\
&= c + T\sum_{r=1}^{2}\log(|\mathbf{A}_{rr}^{(0)}|) - \frac{T}{2}\log(|\Omega|) - \frac{1}{2}\sum_{t=1}^{T}\boldsymbol{\varepsilon_t}'\Omega^{-1}\boldsymbol{\varepsilon_t}.
\end{aligned} \tag{34}$$

For given sample data, expression (34) defines the conditional log-likelihood function of the SpVAR model parameters. Considering the block triangular structure of $\mathbf{C}_0$, induced by the recursive structural identification scheme, the latter is simply the sum of two unrelated terms, each pertaining to the single endogenous variable. As such, each component can be maximized independently from the others, thus reducing the overall computational burden.

However, the likelihood function includes a Jacobian term involving the determinant of an NxN matrix (a feature shared with most common spatial econometric specifications) that can make the optimization process cumbersome or even unfeasible as the spatial sample size increases beyond a given level.

4. **The space-time impulse response function**

By referring to the corresponding reduced form VAR expression, an SpVAR process is said to be stable if the following condition holds

$$\det(\mathbf{I}_{2N} - \widetilde{\mathbf{C}}_1\xi - ... - \widetilde{\mathbf{C}}_p\xi^p) \neq 0 \quad \text{for } |\xi| \leq 1 \tag{35}$$

requiring the roots of the characteristic polynomial to lie outside the unit circle (Lütkepohl, 2007, p. 13).

If the stability condition holds, the SpVAR model admits the following Moving Average representation

$$z_t = \sum_{h=1}^{\infty}\Psi_h\left[\widetilde{\mathbf{G}}\Xi_t + \widetilde{\boldsymbol{\varepsilon}}_{t-h}\right] = \sum_{h=1}^{\infty}\widetilde{\Psi}_h\left[\mathbf{G}\Xi_t + \boldsymbol{\varepsilon}_{t-h}\right] \tag{36}$$

with $\widetilde{\Psi}_h = \Psi_h\mathbf{C}_0^{-1}$.

The $2N$x$2N$ $\widetilde{\Psi}_h$ matrix has the following block structure

$$\widetilde{\Psi}_h = \begin{bmatrix} \widetilde{\Psi}_{11}^{(h)} & \widetilde{\Psi}_{12}^{(h)} \\ \widetilde{\Psi}_{21}^{(h)} & \widetilde{\Psi}_{22}^{(h)} \end{bmatrix} \tag{37}$$

where each NxN block has elements

$$\tilde{\psi}_{kr}^{(h)}(i,j) = \frac{\partial z_{ikt+h}}{\partial \varepsilon_{jrt}} \qquad k,r=1,...,2 \qquad i,j=1,...,N \tag{38}$$

measuring the response of the k-th endogenous variable on location i at time $t+h$ to a one-unit increase in the r-th structural shock on location j and time t.

When the number of regions being analysed is larger than a few units - a situation that is likely to occur in most empirical applications – it rapidly becomes unwieldly to directly inspect the impact of a shock to a given variable on the remaining system variables for each couple of spatial locations in the sample and the various time horizons.

At the same time, even when the number of regions is small, the researcher could be interested in assessing an overall measure of the strength of spatial spillover effects, especially if a spatially homogenous specification has been fitted to the data, in which case impulse responses should exhibit no spatial variation apart from that induced by the spatial weighting scheme itself.

In the context of the univariate Space-Time ARMA model, Di Giacinto (2006) proposed a simple synthetic measure of shock responses by introducing the space-time impulse response (STIR) function. A straightforward extension to the context of the SpVAR methodology is set out in this section.

In particular, the average response at spatial lag s for shocks affecting location i, can be measured alternatively as

$$\begin{aligned} \eta_{kr}^{(h)}(i) &= \sum_{j=1}^{N} w_{ij}^{(s)} \tilde{\psi}_{kr}^{(h)}(j,i) \\ \zeta_{kr}^{(h)}(i) &= \sum_{j=1}^{N} w_{ij}^{(s)} \tilde{\psi}_{kr}^{(h)}(i,j) \end{aligned} \tag{39}$$

where the first expression, that can be referred to as the local outward STIR function, measures the average effect on s-th order spatial neighbours of a unit shock on location i and the second expression, or local inward STIR function, assesses the average effect on location i of a simultaneous unit shock on its s-th order spatial neighbours.

Under spatial homogeneity impulse responses can be further summarized with no loss of information by averaging across space the local STIR function, yielding the following expressions

$$\begin{aligned} \overline{\eta}_{kr}^{(h)} &= N^{-1} \sum_{i=1}^{N} \eta_{kr}^{(h)}(i) \\ \overline{\zeta}_{kr}^{(h)} &= N^{-1} \sum_{i=1}^{N} \zeta_{kr}^{(h)}(i) \end{aligned} \tag{40}$$

that can be referred to as the global outward and inward STIR functions.

The VMA form of the model also allows for the evaluation of the dynamic spatial multiplier effects of shocks affecting global demand or national export competitiveness.

In particular, dynamic effects of macro disturbances on regional export and GDP growth are measured by the response matrices

$$\frac{\partial z_{t+h}}{\partial \Xi'_t} = \widetilde{\Psi}_h \mathbf{G} \tag{41}$$

Applying standard results, long run multipliers measuring the overall impact of exogenous shocks on local dynamics can also be computed by the following expression

$$\sum_h \frac{\partial z_{t+h}}{\partial \Xi'_t} = \widetilde{\Psi}_\infty \mathbf{G} = \left[\mathbf{I}_{2N} - \widetilde{\mathbf{C}}_1 - \ldots - \widetilde{\mathbf{C}}_p\right]^{-1} \mathbf{C}_0^{-1}\mathbf{G}\,. \tag{42}$$

In specific empirical settings, it could be interesting to assess the average degree of transmission of economic disturbances across a few broad partitions of the set of regional economies considered to specify and estimate the model. Assuming that the set of N regions is partitioned exactly in Q groups, $\{G_1, G_2, \ldots, G_Q\}$, the average response, measured after h periods, of the k-th endogenous variable on regions belonging to group G_a to a contemporaneous unit shock to the r-th endogenous variable on regions belonging to group G_b, $a,b=1,\ldots,Q$, $a \neq b$, can be computed as

$$\varphi_{kr}^{(h)}(G_a, G_b) = \sum_{i \in G_a} \sum_{j \in G_b} v_{ij} \widetilde{\psi}_{kr}^{(h)}(i,j) \tag{43}$$

where v_{ij} is a suitable weight, that can be assumed to measure, for instance, the economic mass of the *(i,j)* pair of regions.

5. The empirical study

5.1 Model specification and estimation

In this section the SpVAR methodology outlined above is applied to data for the 20 Italian regions identified at the NUTS2 level of the European classification. Yearly figures for GDP and exports at constant prices are derived from the latest release of the regional Prometeia database, covering the time span 1970-2008.

As regards the two macro variables considered in the model, data for the global volume of merchandise trade is taken from the OECD International Trade dataset while the proxy of export competitiveness at the national level, given by Italy's real effective exchange rate based on relative unit labour costs, comes from the OECD Financial Indicators dataset.

Figure 1 portrays the dynamics of the two regional indicators. While both GDP and exports are trending in levels, growth rates (delta-logs) look stationary, the GDP series showing clear comovements across regions, while exports appear more volatile.

The Im, Pesaran and Shin (2003) panel unit roots test confirm the graphical evidence of non stationarity, failing to reject the null hypothesis that both GDP and exports are I(1). Similar evidence is obtained from Pesaran's (2006) CADF testthat allows for cross-sectional correlation across the regions considered in the panel.

Considering that the Westerlund (2007) panel test fails to reject the null hypothesis that GDP and exports are not cointegrated, the spatial VAR model was subsequently estimated on first-differenced data.

As a preliminary analysis, useful in assessing the strength of the spatial linkages across the given set of regional economies, the space-time auto and cross correlograms for the two series were computed and results are shown in Table 2. The regional GDP growth series displays the highest correlation values, with positive coefficients decaying slowly in time and highly persistent when moving away from the nearest to less closely located regions.

Regional export growth is less persistent in time and the degree of spatial comovement appears also to be much lower than for regional GDP. Cross-correlation estimates show a positive relationship between the two indicators, albeit of small absolute value. Also in this case, correlation levels appear to be persistent in space while time-lagged correlation coefficients look rather small and decay quickly as the lag increases.

Both common macro shocks and a strong spatial spillover mechanism propagating local disturbances can account for the persistent spatial autocorrelation of GDP and exports across regions. To get some preliminary evidence on the influence of common shocks on Italian regional dynamics, space-time correlations were computed a second time based on residuals from the regression of individual regional time series on the two macro indicators. Estimation results, displayed in Table 3, show that the GDP space-time autocorrelation pattern is only marginally affected. Controlling for macro shocks alters the space-time correlograms more markedly in the case of exports, which are more directly linked to global demand and exchange rate fluctuations. In this case smaller, although still significant, autocorrelation coefficients are estimated, while cross-correlation coefficients take small and often non significant values.

The SpVAR model shown in Section 2 involves the use of two different weighting schemes, one pertaining to the spatial diffusion of local technological shocks affecting competitiveness and the other the trade gravity equation. Some effort is thus required in specifying properly the two types of spatial weights matrices.

Considering that information spillovers, differently from trade linkages that are less hampered by distance, are usually assumed to be highly localized, the specification of the spatial weights matrix $W^{(1)}$, as required by equation (7), was based on geographical contiguity, by setting

$$\begin{cases} w_{ij}^{(1)} = 1 & \text{if region } i \text{ and region } j \text{ share a common border,} \\ w_{ij}^{(1)} = 0 & \text{otherwise} \end{cases} \tag{44}$$

$$i,j=1,2,..., N.$$

Higher order matrices were subsequently derived by assuming

$$\begin{cases} w_{ij}^{(m)} = 1 & \text{if a minumu of } m \text{ borders have to be crossed to} \\ & \text{move from } i \text{ to } j, \\ w_{ij}^{(m)} = 0 & \text{otherwise} \end{cases} \tag{45}$$

$$i,j=1,2,..., N, \quad m=2,\ldots,S.$$

Coming to the gravity-based spatial weights w_{ij}^{*}, to make expression (18) operational, a value for the parameter δ has to be selected. A number of alternative values of δ in the range [1/2, 2] were evaluated for this purpose, and the final choice of δ=1 was obtained on the basis of the model's ability to fit the sample data.

To avoid simultaneity, regional GDP shares for the year immediately preceding the sample period were considered in order to compute the gravity-based weights. Over the sample period considered in the analysis, output shares appear to be highly persistent, the correlation between the values recorded in 1970 and in 2008 being equal to 0.99 - this evidence provides strong empirical support to the modelling choice of treating them as fixed constants.

The baseline gravity equation approach implemented in Section 2 yields a precise functional form for the spatial weights w_{ij}^{*}, given by expression (18). However, this specification may turn out to be too restrictive in empirical applications of the model. To gain some more flexibility, the following alternative and more general functional form was considered for the trade-related weights

$$\tilde{w}_{ij}^{*} \cong d_{ij}^{-\delta}\tilde{y}_{j0}^{g} / \Sigma_{j} d_{ij}^{-\delta}\tilde{y}_{j0}^{g} \tag{46}$$

where g is a positive parameter gauging the influence of economic mass on trade flows. When $g = 1$ expression (46) reduces to (18), while for values of $g > 1$ ($g < 1$) more (less) weight is placed on larger trading partners. After a specification search, a value of $g = 0.5$ was deemed to represent the best choice for the dataset considered in the analysis.

While the trade-related weights specified according to the above procedure appeared to fit the data reasonably well, under the monotone decline of spatial interactions imposed by the standard gravity specification the model was not able to account for the peak in spatial autocorrelation observed for the GDP series at spatial lag=2 (see Tables 2 and 3). To overcome this shortcoming, the following adjusted version of the spatial weights matrix W^{*} was finally considered,

$$\tilde{\tilde{W}}^{*} = \tilde{W}^{*} + 0.5W^{(2)} \tag{47}$$

where $\tilde{W}^{*}$ is the NxN matrix with elements $\tilde{w}_{ij}^{*}$ as defined in (46). By placing more weight on spatial interactions among second order spatial neighbours, the model thus re-specified was able to eliminate most of the unwanted residual spatial autocorrelation (see Table 6).

Following standard practice, all spatial weights matrices were finally normalized so that the elements of each row sum to one.

To complete the SpVAR specification, models of different orders in time and space were estimated, considering both constant and varying coefficients across regions. The final selection was based on the evidence provided by usual information criteria, reported in Table 4.

An SpVAR(1,1) model with constant coefficients turned out to represent the specification with the best balance between goodness of fit and parsimony and Table 5 reports the FIML estimates of the corresponding parameters.

5.2 Impulse response analysis

Tables 7 and 8 report the responses at the regional level of exports and GDP to common shocks affecting the two macroeconomic variables featured in the model. Both the direct effect, i.e. the coefficients associated to the single macro variables in equations (6) and (27), and the corresponding dynamic spatial multipliers are reported, distinguishing simultaneous and long run effects.

Direct effects of global demand and real exchange rates on regional export dynamics do not always show the expected sign (positive and negative, respectively), estimated elasticity being generally below unity.

When simultaneous feedback (from exports to GDP) and spatial multiplier effects are allowed for by computing reduced form VMA coefficients at time horizon = 0, elasticities show a general tendency to increase in magnitude.

In the long run, when all dynamic feedback effects across the two endogenous variables and across regions (via trade and technological linkages) have produced their influence, all estimated elasticities show a further significant increase, always taking the expected sign with only one exception. On average exports' elasticity to global demand shocks is above unity in the long run, while the elasticity of foreign sales to shocks to national competitiveness is below unity. Some noticeable spatial heterogeneity across Italian regions shows up as well, albeit with no clear spatial pattern.

As expected, direct GDP responses to the two common shocks is lower than in the case of exports and often take opposite sign compared with what is suggested by economic theory.

In the long run, when all dynamic feedbacks have worked out their effects across the system, elasticities attain larger magnitudes and the expected sign is positive for global demand shocks and negative for real exchange rate fluctuations. On average long run GDP responses appear to display smaller values compared with analogous exports responses.

As explained in the introduction, Italian regions are highly heterogeneous as regards their openness to international trade. Over the sample period the export/GDP ratio ranges from an average of 0.24 in Piedmont to only 0.01 in Calabria.

The direct impact of exogenous fluctuations of world trade and real exchange rates on regions mostly selling their output on the internal market should be negligible. In the long run however, if indirect effects operating through the trade and non-trade inter-regional linkages are strong enough, less open regional economies should also be affected by global shocks.

By allowing for a comparison of direct responses and long run dynamic multipliers the SpVAR model may provide some insights in this respect.

To this purpose, the direct impact estimates and the long run multipliers measuring the influence of fluctuations of world trade and of the real exchange rate of regional GDP growth were regressed on a constant and a binary dummy variable (OPEN), taking unit value in the case of regions with a degree of foreign openness (measured by the average export/GDP ratio over the 1970-2008 period) above the cross-sectional median.

The constant term in the above specification gauges the average effect of macro shocks on less open regions, while the coefficient of the OPEN dummy measures the additional impact on regions that sell a larger share of their output abroad.

In line with expectations, the direct impact of global trade fluctuations on less open regions is negligible, the estimated elasticity being equal to about 0.02 and not statistically different from zero. The differential effect on impact is much larger in more open regions, being slightly above 0.11 on average with a p-value equal to 0.03 (see Table 9).

When the same regression is performed considering the long run multipliers derived from the SpVAR model, the elasticity of GDP growth to global trade dynamics rises to slightly less than 0.5 for the average of the less export-oriented regions, being highly significant. While, there is still evidence of a positive differential in favour of more open regions (equal to about 0.15, in this case), the long run elasticities show that when the shock to global demand has fully propagated through the system via inter-regional linkages the impact on less open regions may be substantial and not much smaller than that estimated for export-led areas.

According to the above elasticity estimates, a 10 per cent drop in international trade volume, a magnitude akin to that recorded over the recent global crisis, would have eventually triggered a GDP fall of about 6.5 per cent in more open regions (mostly located in the North of Italy) and about 5 per cent in the more closed regions (namely in the South). Both figures appear to conform quite reasonably to the accumulated decline of regional GDP observed over 2008 and 2009 (see Banca d'Italia, 2010).

While the above results uncover the existence of strong inter-regional linkages in Italy they do not allow for a separate evaluation of the effects of trade linkages and technological externalities. To provide some details on the relevance of the two propagation channels we hence turn to the analysis of the space-time impulse response function.

Figures 2.a-2.d display the accumulated STIR function (in the outward definition) for both exports and GDP at an increasing time horizon and up to the third order of spatial contiguity.

The response of regional exports to the own structural shock, that can be interpreted as a local supply side disturbance fostering competitiveness at the regional level, is positive and attains a short and long run level of about unity. Positive dynamic spatial spillover effects are estimated for directly contiguous regions (first order spatial neighbours, i.e. regions sharing a common border, in this case) with an elasticity of about 15 per cent, which appear to decay rather quickly moving to higher order neighbours. In line with most empirical findings on the spatial propagation of knowledge, there is therefore some new empirical evidence that the scope of geographical reach of local technological shocks is rather limited in space for Italian regions as well.

The response of regional exports when there are structural shocks to regional GDP, which can be broadly interpreted as demand disturbances on the internal market, is nil within the current period - because of the identifying restriction placed on VAR coefficients - but then tends to accumulate as the predictive horizon increases, attaining a long run value of about 0.4. The spatial propagation of demand side shocks on regional exports appears to be much wider than in the case of supply side disturbances. Spillover effects are estimated to be positive, sizeable and highly persistent across space.

The dynamic response of GDP to local export competitiveness disturbances, while being positive and accumulating over time, attains rather limited values (about 2 per cent in the long run). This low level is not straightforward to interpret and appears to provide some evidence that supply side shocks fostering competitiveness on the export market may have very limited effects on overall local growth in Italy. Perhaps, underlying this low average there are highly differentiated situations across individual regions that ought to be investigated in more detail.

The pattern of the space-time impulse response function is more in line with expectations in the case of the response of GDP to demand side disturbances on the internal market. The instantaneous elasticity is higher than unity, in this case, a situation that can be related to the existence of a spatial multiplier effect, amplifying local disturbances via inter-regional trade linkages. Positive feedback effects tend to accumulate over time, yielding a long run response of about 1.3. Spatial spillover effects are sizeable and tend to accumulate as well, reaching a value of about 0.4 at spatial lag=1, and decaying rather slowly as distance in space increases.

6. Summary and conclusions

Regional economies within a given country usually feature large interdependencies, stemming from both strong bilateral trade flows and knowledge externalities. At the same time local economies are affected by common macroeconomic shocks.

In this paper a structural spatial VAR model is specified that jointly allows for the existence of both macro and local economic disturbances, with a specific focus on trade linkages.

Unobserved trade linkages across regions are modelled by referring to the usual gravity equation approach to trade. The main identifying restriction requires demand shocks to affect regional competitiveness at least with a one period lag, yielding a recursive identification scheme in line with the one recently advocated in Di Giacinto (2010). The model thus specified is fitted to Italian regional time series covering a time span of about 40 years. Based on estimation results, the dynamic multipliers linking individual regional evolutions to common shocks on the foreign markets are assessed first. The scope of the spatial propagation of local shocks across the Italian territory is finally analysed by plotting structural impulse response coefficients, aiming at uncovering spatial spillover effects via internal trade and non-trade linkages.

Empirical findings provide evidence of strong inter-regional linkages, multiplying both the effects of macroeconomic fluctuations and local disturbances. Positive dynamic spatial spillover effects are uncovered for both idiosyncratic supply and demand shocks. Spatial supply-side externalities are found to be positive but decaying quickly with distance. On the contrary, spillover effects appear to be quite persistent across space in the case of internal demand shocks, which are mainly propagated via trade linkages and less hampered by distance.

The evidence of strong internal trade linkages allows for a straightforward reconciliation of the regional GDP dynamics observed in Italy over the last recession, explaining how the far less open regions in the Southern area experienced a pronounced fall in GDP. Estimated dynamic spatial multipliers show in fact how less export-oriented regions, although broadly unaffected on impact, may eventually experience a sharp decline in output after a global trade fall of the size observed over the 2008-2009 period.

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TABLES AND FIGURES

Table 1. Panel unit root and cointegration tests (1)

Test procedure (2)	Im, Pesaran and Shin	Pesaran	Westerlund (3)
	t-bar	*t*-bar	$P\tau$
log (X)	-2.147 (0.443)	-2.233 (0.707)	-
log (Y)	-2.339 (0.122)	-2.529 (0.168)	-
[log (X);log (Y)]	-	-	-10.402 (0.230)

(1) All tests are carried out allowing for a linear trend in the data and lagged differences up to order 2 (*p*-values are given in brackets). (2) *p*-values based on bootstrapped standard errors to allow for cross-section dependence.

TABLE 2. Space-time auto and cross-correlation function for the regional exports and GDP series

Temporal lag	*Spatial lag*				
	0	1	2	3	4
			EXPORTS- EXPORTS		
0	1.000	0.311 ***	0.257 ***	0.168 ***	0.140 ***
1	-0.021	0.036	0.060 ***	0.043 *	0.028
2	-0.019	-0.023	0.003	-0.002	-0.031
3	0.005	0.066 **	0.018	-0.005	0.001
4	0.188 ***	0.045 *	0.002	-0.043 *	-0.006
5	0.003	0.020	0.051 **	0.072 ***	0.046 *
			GDP-GDP		
0	1.000	0.671 ***	0.709 ***	0.646 ***	0.537 ***
1	0.101 **	0.130 ***	0.119 ***	0.170 ***	0.210 ***
2	0.065 *	0.059 **	0.017	0.072 ***	0.060 **
3	0.085 *	0.127 ***	0.117 ***	0.175 ***	0.169 ***
4	0.097 **	0.075 ***	0.054 **	0.031	0.014
5	0.022	0.086 ***	0.081 ***	0.117 ***	0.116 ***
			EXPORTS –GDP		
0	0.169 ***	0.140 ***	0.152 ***	0.159 ***	0.211 ***
1	0.065 *	0.097 ***	0.099 ***	0.022	0.016
2	-0.071 *	-0.065 **	-0.049 **	-0.064 **	-0.010
3	-0.005	0.037 *	0.011	0.056 **	0.019
4	0.076 *	0.050 *	0.042 *	0.067 ***	0.108 ***
5	0.096 **	0.130 ***	0.130 ***	0.153 ***	0.129 ***
			GDP- EXPORTS		
0	0.169 ***	0.164 ***	0.206 ***	0.152 ***	0.195 ***
1	0.078 *	0.154 ***	0.131 ***	0.139 ***	0.046 *
2	0.118 **	0.085 ***	0.157 ***	0.149 ***	0.156 ***
3	0.148 ***	0.089 ***	0.082 ***	0.002	0.001
4	0.045	-0.016	-0.017	-0.010	0.033
5	0.011	0.105 ***	0.015	0.053 **	0.007

*, ** and *** denote statistical significance at the 10, 5 and 1 per cent level, respectively. Spatial auto and cross correlation coefficients computed as in Pfeifer and Deutsch (1980). Spatial lags are defined as the minimum number of borders separating two regions.

TABLE 3. Space-time auto and cross-correlation function for the regional exports and GDP series, after controlling for macro dynamics

Temporal lag	*Spatial lag* 0	1	2	3	4
			EXPORTS- EXPORTS		
0	1.000	0.244 ***	0.099 ***	0.065 **	0.052 *
1	-0.124 ***	-0.047 *	-0.005	-0.027	-0.012
2	-0.114 **	-0.030	-0.052 **	0.005	-0.020
3	0.020	0.102 ***	0.060 **	0.023	0.020
4	0.114 **	-0.002	-0.060 **	-0.088 ***	-0.022
5	-0.066 *	-0.070 **	-0.030	0.017	0.000
			GDP- GDP		
0	1.000	0.569 ***	0.654 ***	0.582 ***	0.502 ***
1	0.227 ***	0.315 ***	0.316 ***	0.329 ***	0.309 ***
2	0.138 ***	0.181 ***	0.148 ***	0.178 ***	0.166 ***
3	0.089 *	0.174 ***	0.161 ***	0.210 ***	0.232 ***
4	0.182 ***	0.189 ***	0.185 ***	0.166 ***	0.161 ***
5	0.081 *	0.190 ***	0.180 ***	0.186 ***	0.156 ***
			EXPORTS-GDP		
0	0.059	-0.006	-0.007	-0.024	0.031
1	0.055	0.135 ***	0.133 ***	0.043 *	0.092 ***
2	-0.029	0.022	0.034 *	0.029	0.071 **
3	-0.032	0.036	-0.005	0.055 **	0.027
4	0.086 *	0.027	0.001	0.032	0.056 *
5	0.019	0.059 **	0.060 ***	0.042 *	0.033
			GDP- EXPORTS		
0	0.059	-0.027	-0.020	-0.058 **	0.023
1	-0.014	0.068 **	0.050 **	0.099 ***	0.001
2	0.031	0.061 **	0.122 ***	0.102 ***	0.111 ***
3	0.130 ***	0.060 **	0.088 ***	-0.011	-0.008
4	0.084 *	0.015	0.036 *	0.061 **	0.044 *
5	-0.024	0.072 **	-0.003	0.053 **	0.022

*, ** and *** denote statistical significance at the 10, 5 and 1 per cent level, respectively. Spatial auto and cross correlation coefficients computed as in Pfeifer and Deutsch (1980). Spatial lags are defined as the minimum number of borders separating two regions.

TABLE 4. Information criteria for alternative SpVAR(*P*,*S*) specifications (1)

	LOGL	*AIC*	*BIC*
Model order	Constant autoregressive coefficients		
P=1 ; S=1	4,042.1	-7,820.2	-7,215.7
P=1 ; S=2	4,058.8	-7,841.6	-7,209.7
P=2 ; S=1	4,050.5	-7,820.9	-7,179.9
P=2 ; S=2	4,071.6	-7,843.2	-7,156.3
	Varying autoregressive coefficients		
P=1 ; S=1	4,253.8	-7,787.6	-6,139.0
P=2 ; S=1	4,399.7	-7,759.4	-5,378.2

(1) All specifications were estimated on the same sample data, including observations from 1972 to 2008.

TABLE 5. FIML estimation results (1)

	ΔX equation		ΔY equation	
	Coefficient		Coefficient	
Spatial-temporal lags:				
ΔX_t	–		0.011	(0.047)
$L\Delta X_t$	0.301	(0.000)	-0.006	(0.394)
$L\Delta Y_t$	–		0.739	(0.000)
ΔX_{t-1}	-0.083	(0.014)	0.005	(0.356)
$L\Delta X_{t-1}$	0.133	(0.000)	0.007	(0.310)
ΔY_{t-1}	-0.030	(0.856)	-0.020	(0.540)
$L\Delta Y_{t-1}$	0.646	(0.000)	0.109	(0.002)
Observations	740		740	
R-squared	0.262		0,580	

(1) The model has been estimated also including a full set of regional dummies, whose results are not reported for the sake of brevity; *p*-values are given in brackets.

TABLE 6. Space-time auto and cross-correlation function of model residuals

Temporal lag	*Spatial lag*				
	0	1	2	3	4
			EXPORTS- EXPORTS		
0	1.000	-0.125***	0.048**	0.030	0.000
1	-0.041	-0.059**	0.018	-0.011	-0.014
2	-0.128***	0.025	-0.053**	-0.001	-0.006
3	-0.002	0.060**	0.007	0.004	-0.019
4	0.109**	-0.017	-0.050**	-0.078***	-0.007
5	-0.029	-0.050*	-0.011	0.005	-0.002
			GDP- GDP		
0	1.000	0.028	0.048**	0.056**	0.045*
1	-0.005	0.001	0.016	0.080***	0.044*
2	0.031	0.071**	-0.074***	-0.002	0.003
3	-0.087*	-0.013	-0.025	0.063**	0.055*
4	0.078*	0.068**	0.045*	0.003	0.014
5	-0.085*	0.037*	0.022	0.046*	0.011
			EXPORTS-GDP		
0	-0.012	0.017	-0.025	-0.068***	0.041*
1	-0.023	0.027	0.093***	-0.053**	0.059*
2	-0.075*	0.005	0.005	-0.002	0.056*
3	-0.065*	0.065**	-0.005	0.046*	0.015
4	0.047	0.038*	-0.014	0.012	0.045*
5	-0.036	0.012	0.012	0.024	-0.011
			GDP- EXPORTS		
0	-0.012	0.007	-0.012	-0.072***	0.032
1	-0.061*	-0.006	0.017	0.070***	-0.056*
2	-0.014	-0.043*	0.021	0.027	0.025
3	0.141***	0.000	0.066***	-0.056**	-0.016
4	0.058	-0.042*	-0.046*	-0.030	-0.010
5	-0.052	0.044*	-0.038*	0.041*	-0.009

*, ** and *** denote statistical significance at the 10, 5 and 1 per cent level, respectively. Spatial auto and cross correlation coefficients computed as in Pfeifer and Deutsch (1980). Spatial lags are defined as the minimum number of borders separating two regions.

TABLE 7. Dynamic multipliers associated to macro disturbances
Response variable: EXPORTS

Italian Regions (NUTS 2)	Shock: Global trade			Shock: Real exchange rate		
	Time horizon			Time horizon		
	Direct impact	0	Long run	Direct impact	0	Long run
Piedmont	0.761	0.744	1.311	-0.065	-0.257	-0.513
Valle d'Aosta	-0.557	-0.334	0.434	-0.905	-0.982	-1.177
Lombardy	0.474	0.576	1.216	-0.262	-0.406	-0.637
Trentino A.A.	0.456	0.623	1.269	-0.246	-0.381	-0.610
Veneto	0.448	0.635	1.284	-0.288	-0.402	-0.600
Friuli V.G.	0.608	0.788	1.431	-0.479	-0.597	-0.780
Liguria	-0.863	-0.686	0.030	-0.654	-0.770	-0.968
Emilia-Romagna	0.091	0.226	0.884	-0.247	-0.392	-0.611
Tuscany	0.771	0.817	1.351	-0.312	-0.490	-0.699
Umbria	-0.130	0.067	0.676	-0.681	-0.827	-0.994
Marche	0.429	0.602	1.145	-0.438	-0.591	-0.779
Latium	0.335	0.550	1.099	-0.139	-0.377	-0.598
Abruzzo	0.940	1.213	1.723	-0.172	-0.452	-0.666
Molise	1.455	1.573	2.048	-1.683	-1.825	-1.861
Campania	-0.314	0.023	0.656	-0.324	-0.556	-0.704
Puglia	-0.567	-0.220	0.426	-0.248	-0.500	-0.644
Basilicata	2.494	2.570	2.940	-0.225	-0.381	-0.497
Calabria	0.324	0.962	1.615	-0.502	-0.502	-0.540
Sicily	1.465	1.679	2.119	0.551	0.386	0.242
Sardinia	0.238	0.457	1.040	-0.575	-0.592	-0.640

TABLE 8. Dynamic multipliers associated to macro disturbances

Response variable: GDP

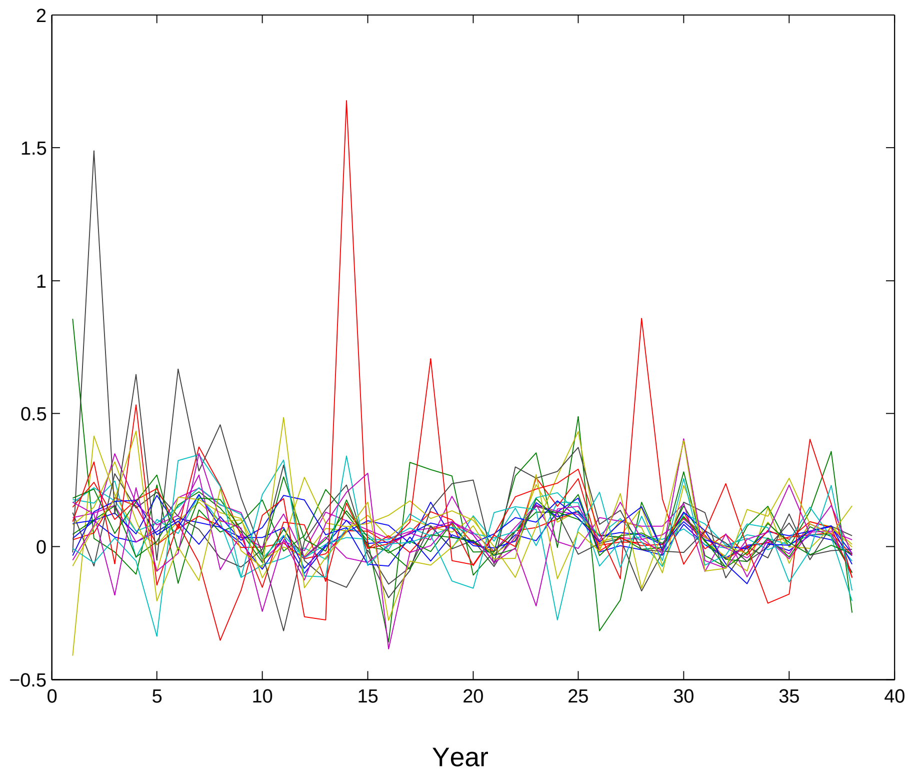
Italian Regions (NUTS 2)	Shock: Global trade			Shock: Real exchange rate		
	Time horizon			Time horizon		
	Direct impact	0	Inf.	Direct impact	0	Inf.
Piedmont	0.207	0.469	0.731	-0.089	-0.148	-0.242
Valle d'Aosta	-0.073	0.200	0.483	-0.129	-0.199	-0.297
Lombardy	0.139	0.398	0.670	0.008	-0.064	-0.158
Trentino A.A.	0.092	0.367	0.637	0.004	-0.065	-0.160
Veneto	0.149	0.405	0.678	-0.037	-0.105	-0.193
Friuli V.G.	0.115	0.389	0.662	-0.102	-0.170	-0.257
Liguria	0.286	0.521	0.781	0.035	-0.033	-0.128
Emilia-Romagna	0.037	0.284	0.555	-0.076	-0.131	-0.221
Tuscany	0.007	0.272	0.534	-0.052	-0.105	-0.195
Umbria	-0.037	0.191	0.450	-0.073	-0.119	-0.207
Marche	0.083	0.336	0.591	-0.072	-0.120	-0.208
Latium	0.027	0.269	0.523	0.068	0.022	-0.068
Abruzzo	0.010	0.237	0.494	0.030	-0.013	-0.101
Molise	-0.124	0.107	0.369	0.020	-0.032	-0.114
Campania	0.098	0.289	0.546	0.037	-0.001	-0.080
Puglia	0.173	0.355	0.607	0.021	0.008	-0.070
Basilicata	0.079	0.310	0.563	0.028	0.016	-0.058
Calabria	-0.179	0.045	0.316	0.042	0.021	-0.046
Sicily	-0.010	0.233	0.480	0.054	0.040	-0.031
Sardinia	0.031	0.251	0.511	0.054	0.013	-0.058

TABLE 9. Foreign openness and the impact of macro shocks on regional GDP growth(*p-values in brackets*)

	Shock: Global trade		Shock: Real exchange rate	
Direct impact:				
Constant	0.016	(0.631)	0.006	(0.739)
Dummy *OPEN* (1)	0.107	(0.031)	-0.041	(0.117)
Observations	20		20	
R-squared	0.232		0.131	
Long run multiplier:				
Constant	0.484	(0.000)	-0.098	(0.000)
Dummy *OPEN* (1)	0.154	(0.001)	-0.089	(0.012)
Observations	20		20	
R-squared	0.450		0.301	

(1) Binary dummy variables indicating regions with an export/GDP ratio above the median.

FIGURE 1: Plot of the regional time series



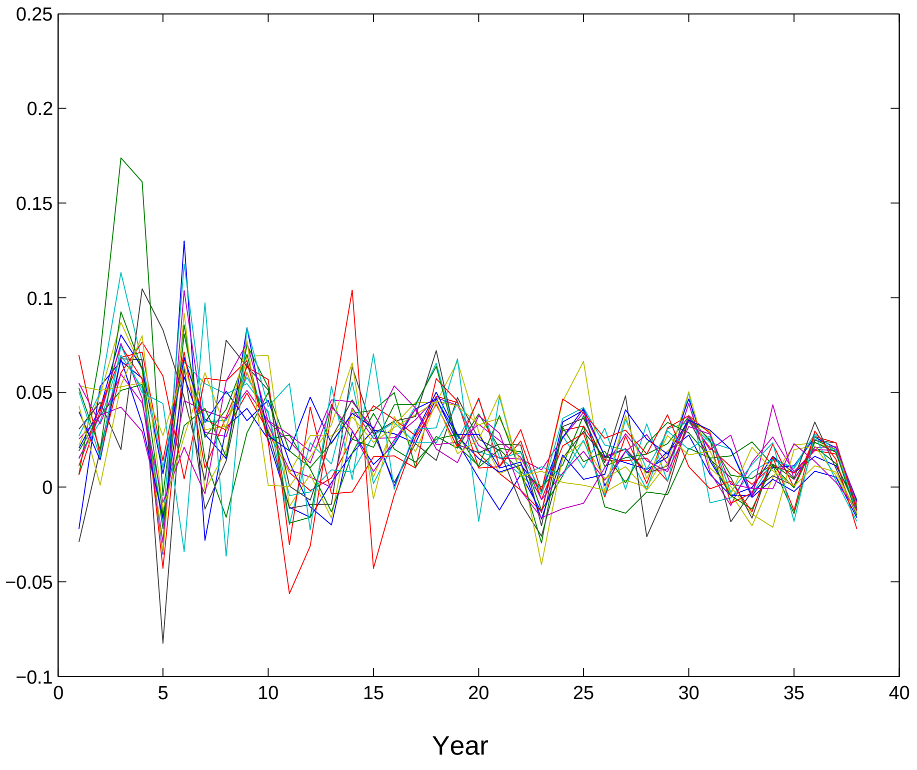
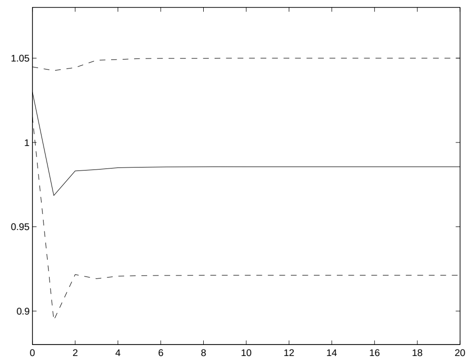


FIGURE 2a: Accumulated space-time impulse responses.

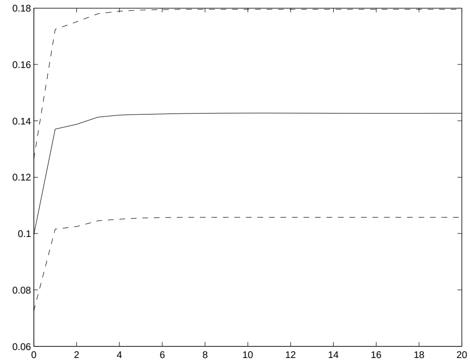
Response: EXPORTS – Shock: internal supply

Spatial lag = 0



Years

Spatial lag = 1



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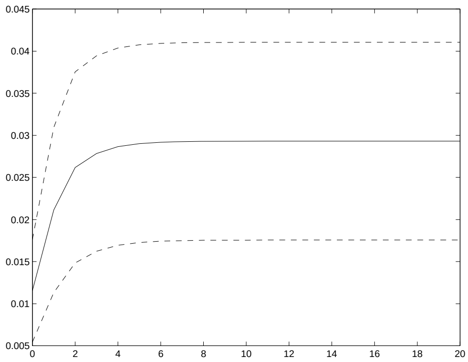
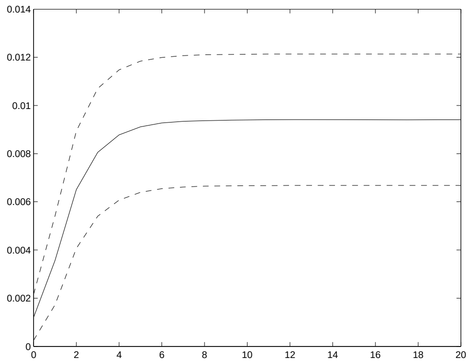
Spatial lag = 2



Years

Spatial lag = 3



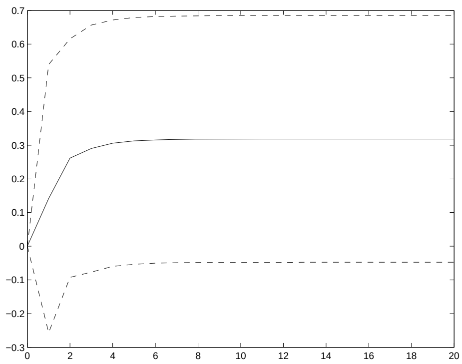
Years

Dotted lines represent 95 per cent bootstrap confidence bands.

FIGURE 2b: Accumulated space-time impulse responses.

Response: EXPORTS – Shock: internal demand

Spatial lag = 0



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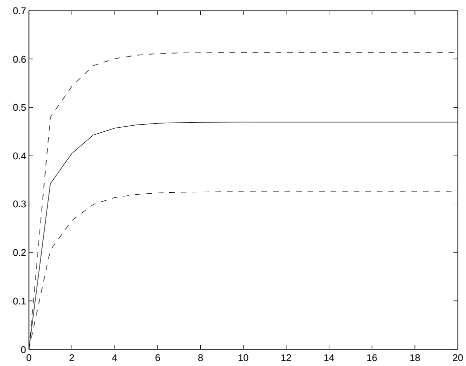
Spatial lag = 1



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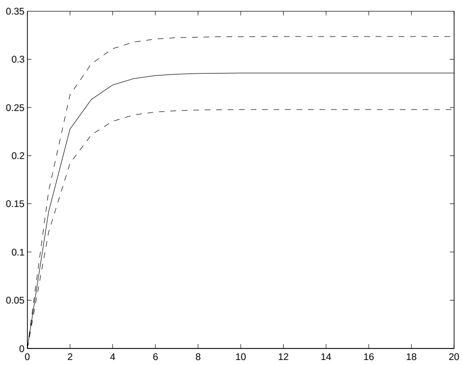
Spatial lag = 2



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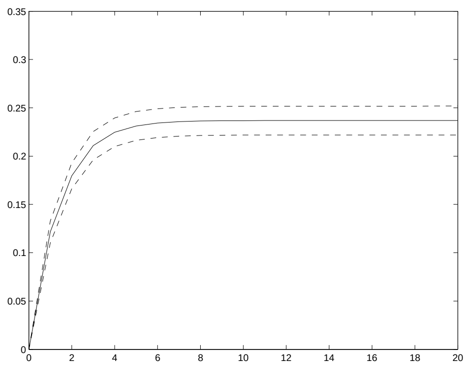
Spatial lag = 3



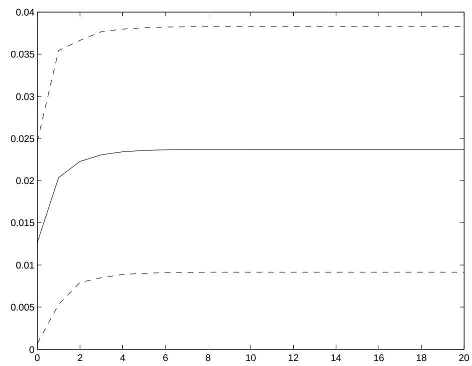
Years

Dotted lines represent 95 per cent bootstrap confidence bands.

FIGURE 2c: Accumulated space-time impulse responses.

Response: GDP – Shock: internal supply

Spatial lag = 0



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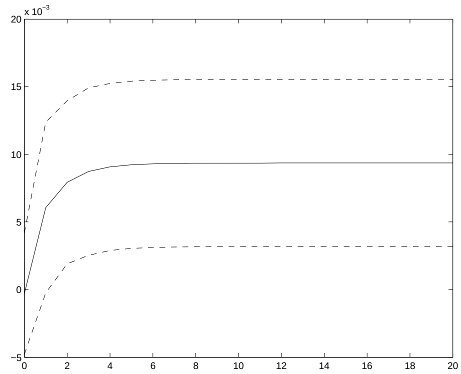
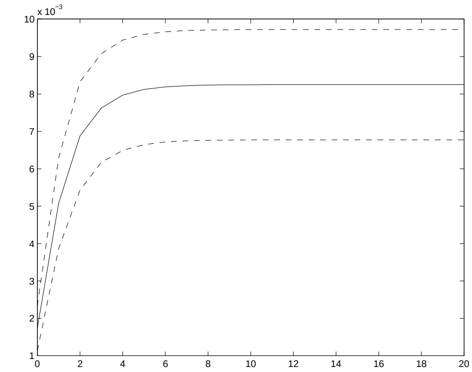
Spatial lag = 1



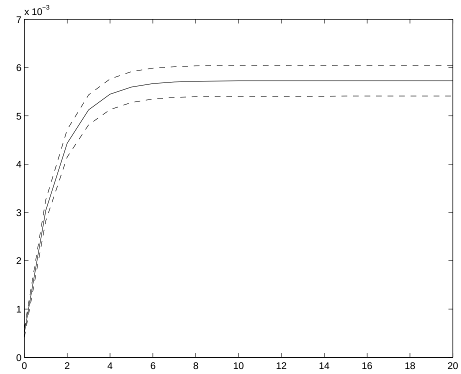
Years

Spatial lag = 2



Years

Spatial lag = 3



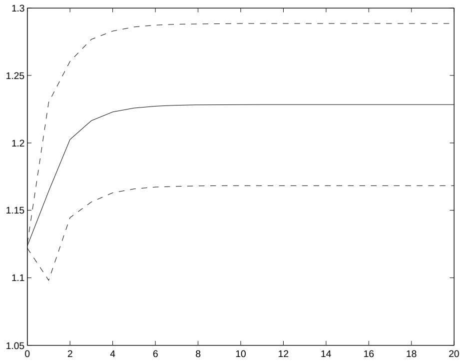
Years

Dotted lines represent 95 per cent bootstrap confidence bands.

FIGURE 2d: Accumulated space-time impulse responses.

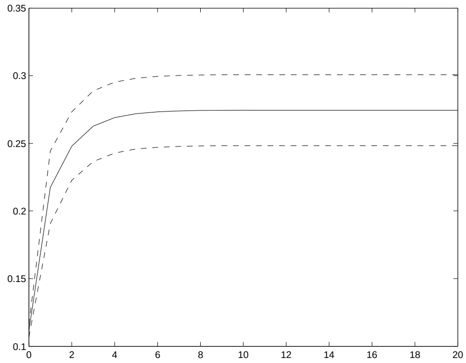
Response: GDP – Shock: internal demand

Spatial lag = 0



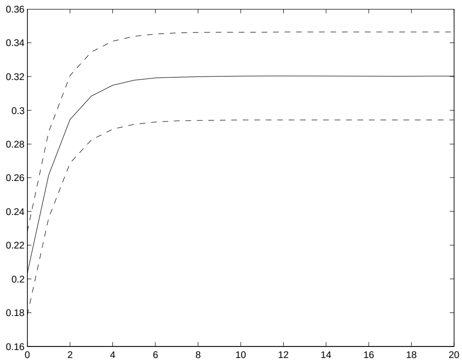
Years

Spatial lag = 1



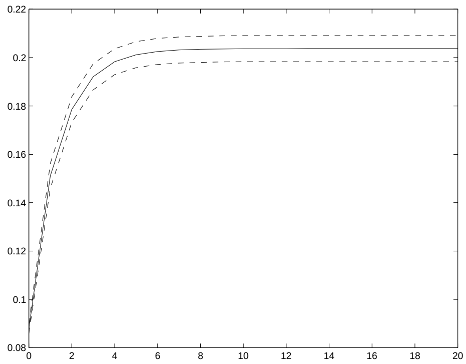
Years

Spatial lag = 2



Years

Spatial lag = 3



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Dotted lines represent 95 per cent bootstrap confidence bands.

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