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Production Externalities, Integration and Growth: The Case of the European Union "Single Market"

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ABSTRACT

The expressed objective of the European Union (E.U.), from its establishment in 1951 with six nations to its subsequent enlargements to include fifteen countries, and its attempts to increase economic integration in 1993 and monetary integration in 1999, has been to promote economic and social progress for the member nations. Interactions and flows of goods within Europe clearly seem to have had productive impacts on the economic performance of the nations as a whole. Such spatial externalities associated with proximity, or localization economies, are likely to have been enhanced by the 1993 and 1999 movements toward a single market and a single currency. In this paper we model and measure the overall production structure of the 15 current E.U. nations for 1985-2000, the productive impacts of spatial externalities between the nations, and the enhancement of these impacts from the economic integration of 1993. We find that the spillover effects were positive and substantive during this time period, particularly in terms of growth rates, but that the further enhancement in 1993 seems negligible. Although our data do not allow consideration of the additional productive benefits of monetary integration, which effectively came into effect at the beginning of 2002, this provides some indication of the potential effects those increased linkages.

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Introduction

Increased openness or integration among nations is generally regarded as having growth-enhancing effects. The European Union is a particularly interesting case for which evidence of such a hypothesis might be sought, due to its expanding linkages over time. The European Union (E.U.) of today is the result of a process of cooperation and integration that began in 1951 between six countries: Belgium, Germany, France, Italy, Luxembourg and the Netherlands. Four sets of accessions, in 1973, 1981, 1985 and 1995 have expanded this base to encompass 15 countries, with the addition of Denmark, Ireland, the U.K., Greece, Spain, Portugal, Austria, Finland, and Sweden. These fifteen member states expanded their economic integration with the establishment of a "single market" in 1993, and monetary integration was launched in 1999, and implemented in January of 2002. The E.U. is now planning further enlargement to include Eastern and Southern European nations.

This sequence of events has been designed to enhance the overall growth of the member countries, by increasing openness and thus economic linkages and flows. One question that might be asked, however, is whether this has had a significant effect. In particular, one might expect linkages to exist simply due to the proximity of these nations, especially given alleged attempts to encourage such connections even before the formal implementation of the single market. To directly evaluate the productive impacts of E.U. policies, one might wish to quantify and assess both the existing economies associated with externalities or linkages among these countries, and the extent to which they were enhanced by further attempts to reduce production barriers, and thus internalize the externalities.

It has increasingly been recognized in the economics literature that there is a geographic or spatial as well as temporal dimension to economic linkages. Such spatial externalities imply that economic activity in one geographic area, in this case a country, affects economic performance in “neighboring” areas. This can occur through various mechanisms, including innovation generation (Krugman), intellectual capital or knowledge (Zucker and Darby), and ideas embodied in goods (Coe and Helpman). As noted by Feldman, such linkages “enhance the generation of innovation and yields higher rates of technological advance and economic growth”, since proximity implies there are linkages among entities within a geographic unit “over which interaction and communication is facilitated,…and economic activity is enhanced.”

One would expect such spillovers to be substantive across European nations, even without the additional boost from increased openness and mobility from policies designed to expand E.U. linkages. To determine the productive impacts of such externalities, and whether they have been augmented or internalized by reducing transactions or other costs that may inhibit productivity, we need to directly establish the productivity-impact of the geographical connections.[1] This requires representing production processes, and generating measures representing spatial productive interdependencies.

Quantitative evidence of spillovers, particularly for the E.U., is limited. Most examples (as outlined in Paul, 2001) stem from trade or location models, and the representation of externalities is often associated with R&D rather than spatial linkages.[2] One exception to this in our context is Fingleton (2001), who shows that productivity levels and growth rates are higher in E.U. regions when other regions – especially financially assisted regions – are

[1] Such impacts are sometimes expressed alternatively as the productive effects of trade liberalization, as in Krauss, or directly in terms of the results of increased trade, as in Johansson.
[2] Although in some cases they are combined, as in Zagler.

experiencing faster growth.[3] A conceptually related study by Johansson explicitly focuses on trade flows, or imports among countries, rather than the somewhat more nebulous idea of spatial spillovers, and finds that trade connections between E.U. countries are more productivity enhancing than from outside the E.U.

A natural framework for modeling and measuring productivity, growth, and spillovers, is that of a production function, representing the output producible from a given amount of inputs, and thus permitting comparison of net output across space and time. This relationship may be expressed in terms of either levels or growth rates, where the latter underscores the time dimension. Accommodating the potential for externalities, or growth effects from country linkages, requires allowing for (internal and external) increasing returns, and including an externality index as an "input" into the production process, as implied by the traditional regional and "new" economic geography and endogenous growth literatures. Recognizing spatial linkages may also be accomplished within the stochastic process by allowing for spatial autocorrelation, as in the spatial econometrics literature.

In this paper we accordingly model and measure potential externalities within the E.U., by estimating a production relationship for the 15 current E.U. nations for 1985-2000, using panel data, including an externality index to capture productive linkages, and allowing for a spatial autoregressive process in the stochastic specification. We adapt the model to recognize potential endogeneity through instruments and cross-effects, and estimate the relationship alternatively, and as a system, in terms of levels and growth rates. We find that increasing returns to scale seem to prevail, particularly with the apparent boost from

[3] Other literature on E.U. growth effects, such as Dlyle and O'Leary, have focused on productive convergence, and find that aggregate productivity has converged, benefiting countries with relatively low productivity levels. It has also been argued by Dunford and Smith that there are costs associated with integration, due to increasing inequality that may arise from economic divergence rather than convergence.

substantive positive externalities across the E.U. nations, which is most significant when technical change biases are recognized, and when the analysis is in terms of growth rates. However, we find negligible evidence of increased performance from the expanding economic integration associated with initiation of the single market in 1993.

The Model

Modeling production relationships and the productive impact of spillovers may be accomplished through a production function specification, adapted to recognize spatial linkages by the inclusion of an externality index in the theoretical model, and spatial autocorrelation in the stochastic model.

The base production relationship takes the simple general form Y=Y(**X**,**T**), where Y is output, **X** a vector of inputs, and **T** a vector of external shift factors. For estimation of such an aggregate production function at the macro level, the value added inputs labor, L, and capital, K, are typically the only inputs included in the model. The most common **T** component is a time counter, t. However, for our purposes we will also include an externality index, or "activity variable", A_W, where A represents the activity of linked sectors (connected by the E.U.), and W indicates that this is a weighted index of such activity. Shifts in the production function between "eras", such as before and after implementation of the single market, may also be represented as fixed effects, or dummy variables representing the hypothesized shift. For the E.U. this involves specifying a dummy variable for the post-1993 time period, D_{93}, for inclusion in the **T** vector. Finally, **T** may include fixed effects representing productive differences across particular observations, such as for countries. For our model the countries are therefore distinguished by fixed effects or dummies, D_N (where N denotes nation).

Building in external impacts explicitly in terms of the expansion of activity in "linked" entities, in this case countries, is analogous to the incorporation of activity variables across industries in Bartlesman, Caballero and Lyons (BCL). BCL construct externality indexes for an industry (industry i) based on the share of material received by or supplied to other industries. That is, $A_W=\Sigma_j w_j a_j$, where a_j is the input level in industry j related to (purchased from or supplied to, depending on whether this is a demand- or supply-side index) industry i, and w_j is the share of products exchanged.

To construct such an externality index in the spatial dimension, as emphasized by Paul (2001) and Cohen and Paul (2001), an initial question to be addressed is what activity variables and weights one might use for this purpose. A natural representation of the spatial linkage, in the context of enhanced production in one unit facilitating production in another connected unit, may be based on the level or growth of production in "neighboring" or linked (through the E.U.) countries. If endogeneity of this measure is thought to be an issue, one might alternatively utilize – directly or as an instrument for production changes – measures of input use in connected sectors (countries), which is more closely related to the BCL treatment. These specifications are thus both considered for our empirical implementation. The weights representing the extent of connection between geographic units could also be based on various representations of the inter-connections among countries; for our analysis we used population weights, as elaborated below.

In the BCL treatment these indexes are incorporated in a simple first-order logarithmic (Cobb-Douglas) production function, expressed in first-differenced form and thus based on growth rates. Although a first-order form is standard for an aggregate production function, since cross-effects are not well represented by such a relationship, it might be of interest also to consider whether including cross-effects provides additional insights about productive patterns. This is especially true for the shift factors, which may have biased impacts. In particular, the time impact on the returns to capital may differ from that for labor.[4] In addition, the single market effect may not be a direct shift effect, but may interact with the externality index to augment its impact. These adaptations to the model therefore are the basis for additional alternative specifications for our empirical application.

Estimation of the function in first-differenced form is also a common practice in the macroeconomics literature, and facilitates direct assessment of the growth impact,[5] although one might think that estimation in levels is preferable because it more naturally supports the representation of returns and scale economies. However, either model might justifiably be used – particularly if there is evidence of strong temporal autocorrelation, which suggests the appropriateness of a differenced form (since it is essentially based on an autocorrelation transformation with the "rho" equal to 1). In addition, in such a circumstance it has been suggested in the recent econometrics literature that systems estimation of an equation in levels along with a differenced form will increase the efficiency of the resulting estimators, especially in the presence of significant temporal autocorrelation. Thus these models comprise alternative specifications for our analysis.

Once these various specifications of the base production function relationship Y=Y(**X**,**T**) are estimated (assuming the functional form does not impose additional structure

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[4] As highlighted in Fingleton (2001), technical change could also vary spatially, which suggests interactions between t and the country dummies, $\mathbf{D_N}$. Our estimates of such a model suggest that the country-specific trend terms capture most of the other effects reflected in other models, including the spillover factors and the contribution of capital. Thus we did not include this specification as part of our empirical results.

such as constant returns to scale), indicators of input productivity, scale economies, technical change, and the productive impacts of externalities are typically constructed as derivatives or elasticities of the function. That is, $\partial Y/\partial X_i$ and $\varepsilon_{Y,Xi} = \partial \ln Y/\partial \ln X_i$ (i=L,K) represent the marginal product and output elasticity or "returns" associated with input X_i; and internal returns to scale are measured as the sum of the output elasticities. In turn, technical progress (growth rate in net output over time) may be captured by $\varepsilon_{Y,t} = \partial \ln Y/\partial t$. Similarly, the externality impact may be evaluated through the proportional "shadow value" $\varepsilon_{Y,AW} = \partial \ln Y/\partial A_W$. The extent to which structural change occurred after 1993 may also be captured by $\varepsilon_{Y,93} = \partial \ln Y/\partial D_{93}$. The sign, size, and significance of these measures thus represent the impacts of the underlying factors on production, or productivity and growth.

Allowing for both internal and external returns to scale is fundamental both theoretically and empirically for representing these relationships. This has been emphasized in the traditional urban and regional economics literatures (Armstrong and Taylor), and more recently the "new" endogenous growth theory (Aghion and Howitt), and the "new" economic geography (Krugman 1991, 1991b) literatures, and underscored in the context of E.U. growth by Fingleton. The notion and existence of increasing returns is particularly relevant when internal and external returns are distinguished, so that external growth effects may augment any existing internal economies, resulting in the potential for on-going or cumulative growth. This implies that the extent of overall "returns" not only to the individual components of **X**, but also to A_W, is important to represent in an unrestricted fashion in the model used for empirical analysis.

[5] The impact on the growth of Y instead of its level is implied by the derivative.

Note also that accommodating the temporal and spatial dimensions and interdependencies in the estimating model might involve not only directly modeling and measuring changes in production processes across time, or associated with spatial linkages, but also recognizing their influence on the stochastic specification. Namely, shocks to some countries may be expected to "spill over" to another closely linked country to some extent. As alluded to above, in the spatial context this involves explicitly recognizing spatial autocorrelation, or spatially autoregressive errors (SAR), analogously to the usual treatment of temporal autoregressive errors (AR1). Models incorporating these stochastic adaptations, and more directly representing temporal dependency through a first-differenced model, also comprise alternative specifications for our estimation of the productivity effects of spatial linkages, and the potential enhancements of these impacts, in the European Union.

Empirical Implementation

The base model used for our estimation of overall productive relationships and impacts of spatial linkages within the E.U. is:

1) $\ln Y_{n,t} = \Sigma_n \delta_n D_{n,t} + \beta_K \ln K_{n,t} + \gamma_L \ln L_{n,t} + \omega_A \ln A_{W,n,t} + \eta_t t + \delta_{93} D_{93} + U_{n,t}$,

where n denotes nation, t time, $A_{W,nt} = \Sigma w_{n,m} Y_{mt}$, the summation is taken over all nations $m \neq n$, and $U_{n,t}$ is a normally distributed error term with zero mean and constant variance. The lack of constraints linking the parameter estimates allows for the estimation to reveal scale economies; for example $\beta_K + \gamma_L = 1$ would be imposed to restrict the model to constant (internal) returns to scale.

The weights $w_{n,m}$ of state m on state n are formalized as $w_{n,m} = 1/|P_n - P_m|$, where P_n is the population in 1990 in country n, and are normalized so $\Sigma w_{n,m} = 1$ (where the summation is taken over all n and $w_{n,n}$ =0). Thus, two countries that are similar in terms of their population size will be given greater weight than two countries that are dissimilar in terms of population. The use of this type of weight structure is common in the literature on spatial econometrics (for example, Case, Hines, and Rosen, 1993).[6]

Theoretical adaptations to this framework involve the incorporation of cross-terms, which could be included for all (non-qualitative) arguments of the function to adapt it to a translog form, or simply to capture selected cross-effects. For example, adding the terms

2) $\beta_{Kt} \ln K_{n,t}\, t + \gamma_{Lt} \ln L_{n,t}\, t + \omega_{A,93} \ln A_{W,n,t} D_{93}$

to (1) represents technical change biases with respect to K and L, and potential post-1993 increases in A_W (separately from the direct shift effect of D_{93}).

Estimation in first differences may also be thought of as a theoretical adaptation or alternative model, although it is also closely linked to adaptation of the stochastic structure. That is, equation (1) in first differences, weighted by the autoregressive or autocorrelation coefficient ρ_{AR1}, may be written as:

3) $\ln Y_{n,t} = \Sigma_n \delta_n D_{n,t} + \beta_K \ln K_{n,t} + \gamma_L \ln L_{n,t} + \omega_A \ln A_{W,n,t} + \eta_t t + \delta_{93} D_{93} - \rho_{AR1} [- \ln Y_{n,t-1} + \Sigma_n \delta_n D_{n,t-1} + \beta_K \ln K_{n,t-1} + \gamma_L \ln L_{n,t-1} + \omega_A \ln A_{W,n,t-1} + \eta_t t_{-1} + \delta_{93} D_{93,-1}] + \varepsilon_{n,t}$,

which is equivalent to

4) $\ln Y_{n,t} - \ln Y_{n,t-1} = \beta_K (\ln K_{n,t} - \ln K_{n,t-1}) + \gamma_L (\ln L_{n,t} - \ln L_{n,t-1}) + \omega_A (\ln A_{W,n,t} – \ln A_{W,n,t-1}) + \delta_{93} (D_{93} - D_{93,-1}] + \varepsilon_{n,t}$,

with ρ_{AR1}=1. (3) is a standard transformation to accommodate temporal dependencies or autoregressive errors, which exist if $\rho_{AR1} \neq 0$. (4) may be estimated as an alternative to (1) if

[6] We also tried using disposable income as P_n but the results indicated that population is the more appropriate weight structure. It is also more likely that population is exogenous, and we did not want to introduce endogeneity in the weight structure.

one wishes to establish the impacts of change in spillovers on growth rates, or if one believes $\rho_{AR1} \approx 1$. Or, as noted above, it may be estimated as a system along with the equation in terms of levels, to increase the efficiency of the resulting estimates.

In turn, stochastic adaptations to the framework include the recognition that A_W could be endogenous, since it is the weighted average of current GDP for all other countries. To address this possibility, the equation may be estimated using instrumental variables techniques, where the instruments for ln A_W are the weighted input use variables ln $\Sigma w_{n,m} L_{m,t}$ and ln $\Sigma w_{n,m} K_{m,t}$, and for each nation n the summation is taken over all countries n≠m ($w_{n,n}$ =0 is imposed). The rationale for choosing these instruments is that they would be expected to be correlated with ln A_W but uncorrelated with the error term, since production function estimation is based on the assumption that the error is uncorrelated with K and L.

Finally, but perhaps most importantly in the context of recognizing spatial linkages, both temporal and spatial autocorrelation may be accommodated in this framework as adaptations of the stochastic framework. As noted above, first-differencing the model may be thought of as a special case of the AR1 adjustment. The SAR (spatial autogressive errors) model may be specified in a similar fashion.

That is, AR1 and SAR are specified in different dimensions, but have a similar conceptual basis. OLS may result in inefficient parameter estimates if either temporal or spatial autocorrelation is present. Doing a SAR correction (as in Cohen and Paul, 2001) involves recognizing that

5) $U_{n,t} = \rho_{SAR} \Sigma w_{n,m} U_{n,t} + \varepsilon_{n,t}$,

where $\varepsilon_{n,t}$ is a white noise error. Using (5) to correct for the possibly erroneous assumption that $U_{n,t}$ is white noise (ρ_{SAR}=0) is analogous to that for an AR1 process, but is based on spatial rather than temporal "lags", resulting in:

$$6)\quad \ln Y_{n,t} = \Sigma_n \delta_n D_{n,t} + \beta_K \ln K_{n,t} + \gamma_L \ln L_{n,t} + \omega_A \ln A_{W,n,t} + \eta_t\, t + \delta_{93} D_{93}$$

$$- \rho_{SAR} [- \Sigma w_{n,m} \ln Y_{n,t} + \Sigma_n \delta_n \Sigma w_{n,m} D_{n,t} + \beta_K \Sigma w_{n,m} \ln K_{n,t} + \gamma_L \Sigma w_{n,m} \ln L_{n,t}$$

$$+ \omega_A \Sigma w_{n,m} \ln A_{W,n,t} + \eta_t \Sigma w_{n,m}\, t + \delta_{93} \Sigma w_{n,m} D_{93}] + \varepsilon_{n,t}\ .$$

Thus, if the estimate of ρ_{SAR} is significantly different from zero, this SAR specification more appropriately accommodates spatial interdependencies than a simple OLS model.

Note that the question of weights again arises for the SAR specification, by contrast to the AR1 adaptation where the time dimension is more straightforward. The lag between periods t and t-1 is better-identified than the multiple linkages with the different geographically connected entities, and their weights. We used the same weights for this purpose as for the construction of the externality index.

The Results

The parameter estimates for the alternative models representing the series of experiments outlined above are contained in Table 1. For the first-order models the parameter estimates are equivalent to output (or output growth) elasticities; for example, for the base model $\varepsilon_{Y,L} = \partial \ln Y/\partial \ln L = \gamma_L$. For the model with cross-effects, these elasticities are constructed as combinations of parameters and data; e.g., for the model including γ_{Lt}, $\varepsilon_{Y,L} = \partial \ln Y/\partial \ln L = \gamma_L + \gamma_{Lt}\, t$. In addition, internal scale economies, SE_I, may be represented by $SE_I = \varepsilon_{Y,L} + \varepsilon_{Y,K}$, and total scale economies including spillovers, or "external" scale effects, SE_E, as

$SE_E = \varepsilon_{Y,L} + \varepsilon_{Y,K} + \varepsilon_{Y,A}$, where $\varepsilon_{Y,K}$ and $\varepsilon_{Y,A}$ are defined analogously to $\varepsilon_{Y,L}$, for K and A_W. These combined measures are presented in the last rows of the table.

First consider the Base run, estimated as (1) with δ_{93}=0, resulting in a standard Cobb-Douglas production with K, L, and t as inputs, augmented by the externality or spillovers index, A_W. We find that the returns to labor are large, at 0.967, and those for capital somewhat small, at 0.113. This implies scale economies of 1.080, or slightly increasing returns to scale. With the spillover effect, these returns rise to 1.174, but the contribution of the spillovers (0.093) is statistically insignificant.

Incorporating also the SAR adjustment, as in the second column of the table, results in similar implications, although the returns to both capital and labor are somewhat lower, so approximately constant internal scale economies are evident. The spillover effect within the function remains statistically insignificant, but the spatial autocorrelation adjustment recognizing linkages among the nations is statistically significant, with a t-statistic of -7.4.

Adding the shift factor for the initiation of the single market, δ_{93}, barely affects these measures, and results in a very insignficant parameter estimate for δ_{93} of 0.007 (t=0.90). Including also the cross-effect between the overall spillover effect and the effects of integration in 1993 results in statistical significance of all these terms. However, the shift factor, δ_{93}, now becomes significantly negative – more than counteracting the positive effect of A_W and the cross-effect between A_W and D_{93} – and substantively decreasing returns to scale emerge, which seems implausible.[7]

[7] A similar pattern emerges if we consider the cross-term, represented by $\omega_{A,93}$, in isolation from the shift factor, represented by δ_{93}. If either term is included in the estimation independently, they are invariably statistically insignificant. If both are included, they counteract each other and the results seem convoluted.

In turn, instrumenting the spillover effect by weighted values of the inputs instead of the output of other nations, to accommodate potential endogeneity embodied in these measures, changes the implications only negligibly.

This sequence of experiments suggests that although adjustment of the stochastic specification to recognize interdependencies among the E.U. nations is statistically important, neither the spillovers among the nations, or the emergence of the single market, seems to have had substantive impacts on the productivity of the E.U. nations. However, further investigation of these relationships reveals that this paucity of evidence may arise from mis-specifying temporal patterns – in particular ignoring potential technical change biases, and characterizing the model in terms of levels. Time trends and growth rates are much more impacted by E.U. linkages and policies than the base production relationships.

This is initially suggested by the changes in the results when one allows for time trends in the returns to capital and labor, or technical change biases, in the next column of the table. It is evident from these measures that the returns to labor are significantly declining over time, and those for capital rising (although not significantly). When this is recognized, the contribution of spillovers becomes significant, and large.[8] The shift term for the emergence of the single market remains, however, insignificantly positive. And although the sum of the first-order terms for K and L suggest approximately constant returns, with the trend terms incorporated in the estimated output elasticities somewhat decreasing (internal) returns are evident, which are augmented by the externality effect to imply large total scale economies.

[8] The value for ω_A seems, in fact, somewhat too large to be plausible, at 0.31, although it the insignificant d93 terms is set to zero this term becomes even more significant, but smaller, at 0.21 (and returns to scale estimates are also more reasonable). The lack of significance of the shift term for the single market thus seems to convolute the estimation of ω_A somewhat in this specification.

This suggests that capturing the time dimension is fundamental for appropriately representing these relationships. Thus, in the next column we present results of a specification incorporating the potential for temporal autocorrelation (AR1) as well as SAR. This specification reduces the statistical significance of the SAR adjustment, and of the spillovers impact – although when the insignificant D_{93} shift factor is omitted its significance is again evident. It also results in an autocorrelation coefficient that is approximately equal to one, suggesting that a preferable specification of the model might be in terms of a first difference, or growth rates, rather than levels.

Note also that the returns to capital become negative, and those to labor smaller, compared to specifications without the AR1 adjustment. However, the fact that the estimated model essentially represents growth rates (with estimated ρ_{AR1}=0.97), implies that the interpretation of these measures should be adapted. In particular, these estimates should not be interpreted as returns to the input (or as the input's contribution to scale economies), but as a decline (or smaller increase) in the marginal product, and thus an increase (or smaller decrease) in the share of capital (labor) over time.

When the model is estimated in terms of growth rates, strong evidence of a contribution of productive spillovers to growth within the E.U. emerges. It also appears that increasing capital growth rates have a somewhat muting impact on output growth rates, but labor growth rates enhance output growth. However, the shift factor for E.U. economic integration through the single market remains insignificant.

Finally, if the equations in levels and growth rates are estimated as a system, as suggested by Blundell et al. and Arellano and Bover, we again find a positive – and even more reasonable in magnitude and very significant – ω_A value, combined with a very small and insigificant δ_{93} value. Although these estimates were computed with ρ_{SAR}=0, because in the model with ρ_{AR1} estimated ρ_{SAR} becomes statistically insignificant,[9] the estimates were similar for alternative values of ρ_{SAR}. In particular, whether the value for ρ_{SAR} was set at 0.5 (as implied by the model with both SAR and AR1 allowed for), zero (implied by the insignificance of the ρ_{SAR} for that model), or -0.8 (as implied by other SAR specifications), the overall story from the estimates remains robust. The implied internal scale economies (which may reasonably be interpreted this way since the function in levels is incorporated) are slightly decreasing in terms of internal inputs, but increasing when spillover effects are recognized, again underscoring the growth impacts of productive spillovers across the E.U. nations.

Summary and Concluding Remarks

In this paper we have explored the productive spillover effects among E.U. nations, and the common belief that the imposition of a single market within the E.U. in 1993 enhanced the productive effects of these linkages by encouraging flows of factors and goods between nations. We find substantive spillover effects for the E.U. countries, especially when time trends and biases are recognized in the model, and particularly in terms of augmented growth rates rather than output levels. And we find that accommodating spatial linkages within the stochastic model is statistically supported, especially for a model specified in terms of output levels, although it does not substantively change the estimated results. We also find, however, negligible evidence of further enhancement of these productive linkages after economic integration was increased by the imposition of the single market. Although

[9] Note also that if ρ_{SAR} is not imposed for this model estimation of the equations embodying the SAR adjustment resulted in unstable estimates. However, since the results are quite robust to alternative imposed values of ρ_{SAR} this does not seem a serious problem with the specification.

our estimate of a further productive shift around 1993 is invariably positive across our specifications, it is also always insignificant.

These conclusions emphasize the importance of recognizing spatial externalities, or what have traditionally been denoted localization or agglomeration economies in the urban and regional economics literature. Such externalities or spillovers seem to have strong growth impacts, suggesting that capturing the spatial dimension of economic interactions, as well as the more commonly represented temporal dimension, has important implications for understanding economic performance of economic entities with spatial interdependencies, such as nations within the European Union.

References

Aghion, Philippe and Peter Howitt. 1998. *Endogenous Growth Theory*. Cambridge, MA: MIT Press.

Arellano, Manuel, and Olympia Bover. 1995. "Another Look at the Instrumental Variable Estimation of Error-Components Models." *Journal of Econometrics*. 68(1), June:29-51

Armstrong, Harvey and Jim Taylor. 1985. *Regional Economics and Policy*. Oxford Press: Philip Allan.

Bartlesman, Eric, Ricardo J. Caballero and Richard K. Lyons. 1994. "Customer- and Supplier-Driven Externalities." *American Economic Review*. 84(4):1075-1084.

Bell, Kathleen P. and Nancy E. Bockstael. 2000. "Applying the Generalized-Moments Estimation Approach to Spatial Problems Involving Microlevel Data." *The Review of Economics and Statistics*. 82(1). February:72-82.

Blundell, Richard, Stephen Bond, and Frank Windmeijer. 2000. "Estimation in Dynamic Panel Data Models: Improving on the Performance of the Standard GMM Estimators." in B. Baltagi (ed.), *Nonstationary Panels, Panel Cointegration, and Dynamic Panels*, 2000, Advances in Econometrics 15, Amsterdam: JAI Press, Elsevier Science.

Case, Ann C., Harvey S. Rosen, and James R. Hines, Jr. 1993. "Budget spillovers and fiscal policy interdependence." *Journal of Public Economics* 52: 285-307.

Cohen, Jeffrey P., and Catherine J. Morrison Paul. 2001. "Agglomeration Effects, Economic Performance, and Location Decisions: The Impacts of Spatial and Industrial Spillovers", manuscript, November.

Doyle, Eleanor, and Eoin O'Leary. 1999. "The Role of Structural Change in Labour Productivity: Convergence Among European Union Countries, 1970-1990." *Journal of Economic Studies*. 26(2-3):106-20.

Dunford, Mick and Adrian Smith. 2000. "Catching Up or Falling Behind? Economic Performance and Regional Trajectories in the New Europe." *Economic Geography*. 76(2). April:169-95.

Feldman, Maryann P. 1999. "The New Economics of Innovation, Spillovers and Agglomeration: A Review of Empirical Studies." *Economics of Innovation and New Technology*. 8(1-2):5-25.

Fingleton, Bernard. 2001. "Equilibrium and Economic Growth: Spatial Econometric Models and Simulations." *Journal of Regional Science*. 41(1) February:117-47.

Johansson, Helena. 2001. “Regional Integration and Productivity Growth: The Case of EU.” *Journal of Economic Integration*. 16(1) March:1-20.

Kelejian, Jarry H. and Ingmar R. Prucha. 1999. “A Generalized Moments Estimator for the Autoregressive Parameter in a Spatial Model.” *International Economic Review*. 40(2). May:509-533.

Krugman, Paul R. 1991a. *Geography and Trade*. Cambridge, MA:MIT Press.

Krugman, P. 1991b. “Increasing Returns and Economic Geography.” *Journal of Political Economy*. 99:483-499.

Krauss, Melvyn. 1997. *How Nations Grow Rich: The Case for Free Trade*. New York and Oxford: Oxford University Press.

Paul, C.J. Morrison. 2001. “Supply and Demand-Driven Spillovers and Productivity Growth.” forthcoming in *Japan and the World Economy*.

Zagler, Martin. 1999. *Endogenous Growth, Market Failures, and Economic Policy*. New York: St. Martin’s Press.

Data Appendix

Employment: Base year data for 1998 and growth rates for 1985 through 2000 from the OECD "statistics portal" website were used to compute annual employment in thousands of workers.

Real GDP: Real GDP per worker for 1984 were taken from the Penn World Tables, and multiplied by the employment numbers for 1984 to obtain real GDP. The growth rates from the OECD "statistics portal" website were then applied to these base numbers to obtain the series for 1985 through 2000.

Capital Stock: Initial year (1984) non-residential capital stock were obtained by multiplying the 1984 non-residential capital stock per worker from the Penn World Tables by the 1984 employment levels derived from the OECD data. Real investment for 1984 were obtained by taking real investment as a share of GDP from the Penn World Tables and multiplying these by the real GDP derived above from the Penn World Tables. Capital stock data for 1985 through 2000 were derived by the perpetual inventory method, assuming a 10 percent depreciation rate. 1984 capital stock per worker data were reported in the Penn World Tables separately for East Germany and West Germany, requiring us to derive estimates for total Germany 1984 capital stock (combined East and West). To accomplish this, we used 1984 employment data to calculate each of East and West Germany's employment as a share of total Germany's workforce. These values were then used to calculate the base capital stock for all of Germany, by taking the sum of the base capital stock per worker for each of East and West Germany times their respective share of workers.

Population: Taken from the Penn World Tables for 1990.

Country Coverage: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.

Estimation Time Period: 1985-2000.

Table 1: Parameter estimates and t statistics, alternative specifications

	Base		***SAR***		***with*** δ_{93}		***with*** $\omega_{A,93}$		***INST***	
δ_1	1.110	*0.42*	4.235	*2.25*	3.172	*1.43*	1.917	*0.91*	2.645	*1.14*
δ_2	1.240	*0.47*	4.364	*2.33*	3.304	*1.49*	2.052	*0.98*	2.778	*1.19*
δ_3	1.102	*0.43*	4.193	*2.28*	3.156	*1.45*	1.929	*0.94*	2.641	*1.16*
δ_4	1.210	*0.47*	4.299	*2.33*	3.262	*1.50*	2.018	*0.98*	2.744	*1.20*
δ_5	1.021	*0.37*	4.292	*2.26*	3.200	*1.42*	2.040	*0.96*	2.669	*1.13*
δ_6	0.954	*0.37*	4.274	*2.38*	3.238	*1.52*	2.259	*1.13*	2.739	*1.22*
δ_7	0.620	*0.23*	3.717	*1.92*	2.616	*1.14*	1.266	*0.58*	2.071	*0.86*
δ_8	1.130	*0.43*	4.141	*2.19*	3.078	*1.38*	1.715	*0.81*	2.546	*1.09*
δ_9	1.159	*0.45*	4.427	*2.46*	3.392	*1.59*	2.361	*1.18*	2.890	*1.29*
δ_{10}	1.686	*0.59*	4.551	*2.19*	3.420	*1.41*	1.702	*0.73*	2.835	*1.11*
δ_{11}	1.139	*0.42*	4.293	*2.26*	3.214	*1.43*	1.958	*0.92*	2.681	*1.14*
δ_{12}	0.458	*0.17*	3.545	*1.83*	2.431	*1.06*	1.067	*0.49*	1.884	*0.78*
δ_{13}	0.973	*0.38*	4.189	*2.35*	3.164	*1.49*	2.111	*1.06*	2.666	*1.20*
δ_{14}	1.170	*0.43*	4.297	*2.24*	3.209	*1.41*	1.901	*0.89*	2.670	*1.12*
δ_{15}	0.955	*0.36*	4.221	*2.32*	3.164	*1.46*	2.103	*1.03*	2.655	*1.17*
ω_A	0.093	*0.64*	0.098	*0.91*	0.157	*1.24*	0.281	*2.30*	0.187	*1.42*
δ_{93}					0.007	*0.90*	-0.595	*-3.85*	0.008	*1.02*
$\omega_{A,93}$							0.032	*3.90*		
β_K	0.113	*2.57*	0.073	*2.31*	0.067	*2.10*	0.054	*1.83*	0.069	*2.15*
γ_L	0.967	*14.07*	0.923	*14.15*	0.927	*14.17*	0.842	*12.57*	0.918	*13.78*
η_t	0.014	*3.25*	0.016	*5.16*	0.015	*3.88*	0.012	*3.44*	0.014	*3.51*
β_{Kt}										
γ_{Lt}										
ρ_{SAR}			-0.824	*-7.36*	-0.832	*-7.43*	-0.989	*-8.05*	-0.833	*-7.44*
ρ_{AR1}										
SE_I	1.080		0.996		0.995		0.897		0.987	
SE_E	1.174		1.094		1.151		1.178		1.175	
$\varepsilon_{Y,K}$										
$\varepsilon_{Y,L}$										
$\varepsilon_{Y,t}$										

Table 1(Cont.): Parameter estimates and t statistics, alternative specifications

	t biases		*with AR1*		*AR1 w/out* δ_{93}		*growth rates*		*system*	
δ_1	-1.117	*-0.54*	3.755	*1.77*	1.491	*0.98*	0.0013	*2.78*	*0.0017*	*3.31*
δ_2	-0.979	*-0.47*	3.783	*1.78*	1.491	*0.98*	0.0008	*1.54*	*0.0016*	*3.08*
δ_3	-1.070	*-0.53*	3.419	*1.67*	1.239	*0.84*	0.0010	*2.06*	*0.0014*	*2.59*
δ_4	-0.973	*-0.48*	3.775	*1.82*	1.587	*1.06*	0.0018	*3.81*	*0.0029*	*5.70*
δ_5	-1.122	*-0.53*	4.282	*1.97*	1.978	*1.28*	0.0006	*1.17*	*0.0013*	*2.55*
δ_6	-0.918	*-0.45*	4.472	*2.14*	2.346	*1.59*	0.0005	*1.12*	*0.0015*	*2.83*
δ_7	-1.773	*-0.83*	2.922	*1.36*	0.563	*0.36*	0.0008	*1.61*	*0.0004*	*0.74*
δ_8	-1.236	*-0.60*	3.799	*1.70*	1.519	*0.93*	0.0038	*8.28*	*0.0020*	*3.89*
δ_9	-0.777	*-0.38*	4.454	*2.13*	2.316	*1.57*	0.0007	*1.51*	*0.0020*	*3.79*
δ_{10}	-1.141	*-0.51*	3.784	*1.59*	1.222	*0.68*	0.0056	*11.16*	*0.0044*	*7.71*
δ_{11}	-1.106	*-0.53*	3.721	*1.76*	1.455	*0.96*	0.0009	*1.97*	*0.0003*	*0.49*
δ_{12}	-1.984	*-0.92*	3.090	*1.39*	0.711	*0.45*	0.0021	*4.66*	*0.0006*	*1.12*
δ_{13}	-0.987	*-0.49*	4.051	*1.96*	1.947	*1.33*	0.0010	*2.18*	*0.0009*	*1.66*
δ_{14}	-1.146	*-0.54*	3.747	*1.75*	1.413	*0.92*	0.0011	*2.19*	*0.0021*	*3.96*
δ_{15}	-1.054	*-0.51*	4.300	*2.03*	2.133	*1.42*	0.0006	*1.06*	*0.0013*	*2.49*
ω_A	0.315	*2.78*	0.129	*1.15*	0.308	*3.27*	0.5419	*3.77*	*0.1850*	*31.11*
δ_{93}	0.013	*1.57*	0.178	*1.02*			0.0003	*0.92*	*0.0009*	*2.00*
$\omega_{A,93}$										
β_K	0.040	*1.32*	-0.048	*-2.12*	-0.044	*-2.24*	-0.0250	*-3.06*	*0.016*	*1.65*
γ_L	0.964	*17.87*	0.692	*10.11*	0.655	*9.16*	0.4268	*8.05*	*0.959*	*61.77*
η_t	0.051	*9.66*	0.007	*0.40*	0.022	*3.21*	0.0000	*-0.64*	*0.000*	*-2.02*
β_{Kt}	0.002	*1.80*								
γ_{Lt}	-0.007	*-5.66*								
ρ_{SAR}	-0.343	*-2.73*	0.049	*1.06*	-0.114	*-0.88*	-0.207	*-1.12*	0.000	
ρ_{AR1}			0.966	*44.57*	0.966	*41.77*			1.000	
SE_I	0.964		0.643		0.611		0.402		0.975	
SE_E	1.279		0.773		0.919		0.944		1.160	
$\varepsilon_{Y,K}$	0.059									
$\varepsilon_{Y,L}$	0.905									
$\varepsilon_{Y,t}$	0.003									