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► **To cite this version:**

Stefano Schiavo. Financial Integration, GDP Correlation and the Endogeneity of Optimum Currency Areas. *Economica*, 2008, 75, pp.168-189. 10.1111/j.1468-0335.2007.00598.x . hal-01022326

**HAL Id: hal-01022326**

**<https://sciencespo.hal.science/hal-01022326>**

Submitted on 10 Jul 2014

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# Financial Integration, GDP Correlation and the Endogeneity of Optimum Currency Areas

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Final version received 3 July 2006.

The paper analyses the relationship between trade, financial integration and business cycle synchronization in the euro area. The introduction of the euro has had a noticeable impact on European financial markets. Evidence that capital market integration exerts a positive effect on output correlation has two major implications. First, it corroborates the hypothesis of the endogeneity of optimum currency areas, whereby after joining a monetary union countries better meet standard OCA criteria; second, it provides European policy-makers with yet another reason to pursue financial integration in the euro area (and in prospective members as well).

## INTRODUCTION

This paper investigates the relation between trade integration, financial integration and the correlation of business cycles in the euro area. Since the early 1990s, measures have been implemented to eliminate restrictions on European capital markets and increase their amalgamation. Well functioning financial markets facilitate the efficient allocation of resources and thereby spur economic growth; moreover, integration of capital markets increases the risk-sharing possibilities faced by individuals and their chances to hedge against idiosyncratic shocks. The relevance of this latter aspect has been growing with the prospect of a European monetary union, as capital mobility is one of the standard criteria proposed by optimum currency area (OCA) theory.

Recent empirical work (Imbs 2004) suggests that more financially integrated countries display more correlated business cycles. This has important implications for the euro area, as it means that financial integration reduces the costs of a single monetary policy and thereby provides European policy-makers with yet another reason to pursue it. On more theoretical ground, this view supports the hypothesis that optimum currency areas are endogenous.

The static nature of traditional OCA criteria was first emphasized by Frankel and Rose (1998), who assume that currency unions increase bilateral trade and find a positive relation between the latter and business cycle correlation. More recently, the hypothesized effect of monetary unions on trade flows has been under intense scrutiny, stimulated by Rose (2000) who reports a very large effect.

The claim that increased commercial integration lowers the cost of a single monetary policy through its effect on GDP synchronization therefore seems well established—so much so that nowadays trade is customarily included among the determinants of GDP correlation, as is confirmed by recent work by Baxter and Kouparitsas (2004) and Inklaar *et al.* (2005).

Thus far, research concerned with the endogenous effects of a currency union has focused almost exclusively on the trade channel, while other possible sources of endogeneity have not been directly explored (a notable exception being De Grauwe and Mongelli 2005). By exploiting a number of recent empirical contributions, this paper addresses the financial side of the endogeneity hypothesis. The first and foremost

contribution of this work is the identification of a second mechanism making a currency area more justifiable *ex post* than *ex ante*. Second, building on the simultaneous equations framework put forward by Imbs (2004), the paper accounts for the indirect channels and interactions linking business cycle correlation, its determinants, and the adoption of a single currency. Finally, I distinguish explicitly between sectoral specialization and similarity of economic structures—which tend to be treated as antonyms in the existing literature—in the belief that, at the level of disaggregation common to this kind of analysis, they represent complementary rather than mutually exclusive phenomena.

The paper is organized as follows. The next section discusses in more detail the notion of endogeneity with respect to OCA theory and provides a context for the rest of the analysis. Section II reviews recent empirical contributions that constitute the building blocks for my work, while Section III describes the data and the econometric methodology employed. Results are presented in Section IV, while the final section discusses the main conclusions and identifies some avenues for further research.

## I. SOURCES OF ENDOGENEITY

### *Exposure to asymmetric shocks*

Owing to the original use of the notion by Frankel and Rose (1998), in the context of OCA theory endogeneity is normally taken to mean a change, triggered by the adoption of a single currency, in the nature of the shocks faced by member countries. This in turn alters the costs and benefits associated with the surrender of monetary independence. Frankel and Rose find that, by enhancing trade integration, the use of a common currency increases business cycle synchronization and thereby reduces the need to operate exchange rate adjustments (to maintain an independent monetary policy). Of course, this is not the only possible source of endogeneity.

A second relevant channel—which has not been thoroughly investigated so far—is represented by capital markets.

International financial integration holds a prominent place in the theory of OCA: in his original contribution, Mundell (1961) defines the optimum domain of a monetary union as one in which there is full mobility of factors of production. By substituting for exchange rate movements, in fact, factor mobility has equilibrating effects in the wake of local asymmetric shocks and reduces the costs associated with the loss of monetary sovereignty. Ingram (1962) notes that high capital mobility can substitute for exchange rate movements and buffer the economy from adverse temporary shocks. This notion is further developed in Mundell (1973), where the future Nobel Prize winner discusses the role of international risk-sharing via cross-country holding of assets.<sup>1</sup>

While these approaches suggest that, *ceteris paribus*, capital mobility lowers the costs associated with permanently fixing the exchange rate and losing control over monetary policy, I recognize that the introduction of a single currency is going to have profound effects on financial markets and to feed back into the system.

The first (trivial) point to note is that the elimination of exchange rate risk will sweep away one of the main determinants of market segmentation, will increase asset substitutability, and therefore will raise the mobility of capital. Hence the threshold level of *ex ante* financial integration required for the benefits of monetary unification to outweigh associated costs is reduced by means of this process of cumulative causation.

The second channel replicates the mechanism highlighted by Frankel and Rose (1998) in the case of trade. In fact, recent empirical findings point to the fact that financially integrated economies tend to display more tightly correlated cycles.

A third point, which is related to the previous one, concerns the effect of European integration, and of monetary unification in particular, on sectoral specialization patterns. Most models in international trade theory predict that a reduction in transaction costs induces specialization, in order to exploit comparative advantages (Ricardian theory), factor abundance (Heckscher–Ohlin model) and economies of scale (new trade theory) or of location (new economic geography). A similar conclusion holds for financial integration and follows from the risk-sharing argument reviewed above: capital market integration—allowing for cross-border ownership of assets and means of production—relaxes the trade-off between specialization and the insurance properties of a diversified portfolio of industrial sectors. While concentrating on more productive sectors grants higher returns, it makes the system more exposed to asymmetric shocks; financial integration would provide agents with better insurance against (non-systemic) production risk and therefore enhance specialization.

Most studies investigating the impact of European (monetary) integration on national industrial structures assume that more specialized economies display less synchronized cycles: yet this is not necessarily true, at least on theoretical grounds. Obstfeld (1994), for instance, sets up an open-economy model whereby international financial integration encourages all countries to shift away from a low-return, safe investment to a high-yielding, risky one. The same could happen once capital market integration allows firms that operate in risky sectors, and are therefore more dependent on external finance, to have a wider access to financial funds. In this case European countries would experience simultaneously both increased specialization and increased similarity of their industrial structure as those sectors experience a generalized growth.

So far I have discussed endogeneity in the sense of a feedback loop from monetary integration to business cycle correlation, and I have identified three main channels through which this can occur: trade integration, financial integration and industrial specialization. Although this notion of endogeneity is the most common in the context of OCA theory—and it is the one to which I will refer throughout the rest of the paper—these are not the only mechanisms by which the decision to surrender exchange rate independence may affect *ex post* the costs and benefits of monetary unification.

### *Transmission of shocks and policy responses*

Exposure to asymmetric shocks may not be the sole reason why members of a currency union are out of phase. Farina and Tamborini (2004), for instance, present an interesting model where, given the institutional design of EMU, the main culprit lies in the presence of structural asymmetries.<sup>2</sup>

Aside from the trivial case of asymmetries in the propagation of the shocks (which is tantamount to the presence of asymmetric shocks), there may be differences in the transmission of the common monetary policy. The budgetary limits imposed upon fiscal authorities entail that automatic stabilizers alone are not able to fully stabilize the economy, so that some residual volatility is transmitted to the whole monetary union and will trigger central bank intervention. Then, as a result of different transmission mechanisms, the common monetary policy will not fit all countries and may even generate ‘perverse’ outcomes whereby cross-country dispersion of output gaps increases.<sup>3</sup>

The last reason to believe that monetary integration may affect the response of the economy to shocks is its potential effect on monetary policy transmission mechanisms. Deeper financial integration is likely to have an impact on the institutional and legal framework governing financial flows, the functioning of financial markets and the transmission of policy impulses. Using Farina and Tamborini's terminology, one can imagine that, via its effect on financial market integration, the introduction of a single currency would reduce the structural asymmetries that tend to cause 'perverse' effects.

The main difference between the 'endogeneities' described in the previous section and those reviewed here lies in the fact that the latter originate from the interaction between the adoption of a single currency and the institutional design regulating the functioning of *a particular* currency area. On the contrary, one can regard the former as having a more general content and applying to *every* monetary union. For this reason, in what follows I shall focus exclusively on the first type of endogenous effects: the feedback loop from monetary integration to business cycle correlation, placing particular emphasis on the role of financial integration.

## II. A GLANCE AT THE EXISTING LITERATURE

Relevant contributions can be classified in two broad families according to their main focus: (i) the impact of EMU on European capital markets and (ii) determinants of output correlation and the role of financial integration.

### *European capital markets after the euro*

The elimination of exchange rate risk enhances substitutability among securities issued in different countries, and increases transparency. This in turn facilitates competition and arbitrage and thus reduces the cross-sectional dispersion of prices and returns. Moreover, using a single unit of account removes currency matching requirements for financial intermediaries and therefore fosters cross-border financial flows. There is a wide consensus on the notion that the introduction of the single currency has spurred financial integration in the euro area both directly (through the elimination of currency risk and the standardization of contracts) and indirectly (by reducing the cost of cross-country transactions and increasing competition in the banking sector).

In two early studies, Galati and Tsatsaronis (2001) and Karlinger (2002) claim that the euro contributed to a reduction in the financial market segmentation by relaxing technical, regulatory and psychological constraints that had been hindering integration until 1999.

A comprehensive assessment of the impact of EMU on financial markets is presented by Baele *et al.* (2004): they find that, although the impact of the single currency has been particularly quick and pronounced on bond markets (see also Hartman *et al.* 2003; Pagano and von Thadden 2004; Cappiello *et al.* 2006), all market sectors have shown a marked increase in integration.

Additional indirect evidence is provided by those studies that investigate the nature of remaining spreads among government bond yields. They find little role for local factors and therefore dismiss explanations based on liquidity risk and residual market segmentation (Codogno *et al.* 2003; Pagano and von Thadden 2004). Greater integration is also suggested by Blanchard and Giavazzi (2002), who find that the correlation

between domestic saving and investment has declined over time, especially in the euro area.

In a more recent contribution, De Santis and Gérard (2006) find that the single currency has enhanced regional financial integration above and beyond the global trend.

### *Integration, specialization and output correlation*

The relation between integration and business cycle synchronization is not clear-cut. Advocates of the specialization paradigm (Krugman 1993) claim that the former fosters specialization and therefore makes countries less synchronized. Early studies on the issue have tried to assess the impact of European integration on the industrial structure of member countries. Most empirical contributions, however, predate EMU and focus on the integration of real, rather than financial, markets.

This being said, it is worth noting that no well defined implications emerge from the data, as results appear to be sensitive to the level of regional disaggregation (Martin 2001) and to the variable chosen to measure sectoral activity: Brühlhart (2001) reports different findings for trade, production and employment data. Brühlhart and Traeger (2005) find little support for the hypothesis that strong sectoral reallocation trends across economic activities have taken place between 1975 and 2000. Midelfart *et al.* (2003) conclude that, while monetary unification increases specialization, the size and relevance of industry-specific shock is very small and does not raise the cost of monetary policy.

Following Frankel and Rose (1998), a number of studies have focused on the relation between trade and output correlation. For instance, recent work by Inklaar *et al.* (2005) finds support for the role of bilateral trade intensity, although the authors stress that other factors (policy coordination, specialization, financial integration) are equally important. Along the same lines, Otto *et al.* (2001) confirm (i) an important role for trade, and (ii) a less robust performance by finance (whose significance depends on the chosen measure), while (iii) policy coordination and specialization patterns are not significant. Similar results can be found in Baxter and Kouparitsas (2004), while Fidrmuc (2004) stresses that it is intra-industry trade that drives synchronization.

Yet there are also some dissenting voices: Doyle and Faust (2003) show that, despite the large increase in economic integration experienced by G7 countries, there is no evidence of a significant shift in correlations; while Camacho *et al.* (2005) find that international economies have become less synchronized over the last fifteen years. Alesina *et al.* (2002) claim that currency unions do not bring about co-movements in output (as opposed to Rose and Engel, 2002); moreover, it is not clear whether a European business cycle has emerged as a result of increased integration (Artis and Zhang 1997; Artis 2003; Giannone and Reichlin 2006).

For what concerns more specifically financial integration, Kalemli-Ozcan *et al.* (2001, 2003) provide empirical support for the hypothesis that financial integration, by promoting specialization, is conducive to less synchronized cycles. These findings clash with the conclusions reached by Rose and Engel (2002) and Darvas and Szapáry (2004). Using a simultaneous equation framework that accounts for the interactions between trade, finance, industrial specialization and output co-movements, Imbs (2004) notes that financially integrated economies are more synchronized despite the fact that they are also more specialized.

There are two ways to reconcile these opposite claims. First, financial integration raises risk-sharing (Kalemli-Ozcan *et al.* 2003) and therefore smooths the effects of asymmetric shocks. Whether the insurance provided by the international cross-holding of

assets and liabilities is enough to offset the increased number of shocks provoked by specialization is an open empirical question. Second, the link between financial integration and specialization is not unambiguously determined, as countries may well specialize in similar sectors characterized by a greater reliance on external finance (Obstfeld 1994; Rajan and Zingales 1998).

### III. METHODOLOGY AND DATA

This paper pursues two different methodologies in order to identify the role of financial integration in determining output correlation.

First, I use single-equation estimation to gauge the effects of trade, finance, specialization and similarity of industrial structure on GDP co-movements. Following Otto *et al.* (2001), I move from simple to complex and start from a bivariate specification where business cycle synchronization is regressed on each of the explanatory variables in turn. This approach limits colinearity problems but clearly pays a high price in terms of explanatory power, and the results give only a coarse representation of the relation of interest. Multivariate regressions are then presented and discussed, from which it is possible to derive a more complete picture.

The second step exploits the simultaneous equation approach suggested by Imbs (2004), which grants one the possibility of more adequately investigating the complex system of interactions among trade, finance, specialization and synchronization. In its original specification, the system of simultaneous equations read as follows:

$$(1) \quad \rho = \alpha_0 + \alpha_1 F + \alpha_2 T + \alpha_3 S,$$

$$(2) \quad F = \beta_0 + \beta_1 X^F,$$

$$(3) \quad T = \gamma_0 + \gamma_1 S + \gamma_2 X^T,$$

$$(4) \quad S = \delta_0 + \delta_1 F + \delta_2 T + \delta_3 X^S,$$

where  $\rho$  measures output correlation,  $F$  financial integration,  $T$  bilateral trade flows and  $S$  sectoral similarity, and where  $X^*$  are additional controls needed to achieve identification.

While Imbs (2004) used a pure cross-sectional data-set, I adopt a panel approach and investigate the behaviour of 190 country pairs over the period 1991–2002.<sup>4</sup> To acquire a meaningful measure of GDP correlation, the 12 years have been divided into three subperiods of four years each, and quarterly real GDP data (taken from the OECD *Main Economic Indicators*) are used to compute synchronization.

Three measures of business cycle synchronization are employed: (i) the correlation between GDP series filtered via a band-pass filter *à la* Baxter and King (1999); (ii) the correlation between fourth-lag log-differences; and (iii) a measure based on the innovations from an AR(2) process as used in Alesina *et al.* (2002). In the regression analysis the first two indicators are further transformed to account for the fact that sample correlations must lie between  $-1$  and  $1$  (see the Appendix for details).

Trade data come from the IMF *Direction of Trade Statistics*, and bilateral trade intensity is measured as the sum of imports and exports weighted by the sum of GDPs:

$$T_{ij} = \frac{\text{exp}_{ij} + \text{imp}_{ij}}{\text{GDP}_i + \text{GDP}_j}.$$

As opposed to Imbs (2004), who opts for quantity-based measures, I used price-based indicators to measure financial integration. In this choice I was backed by a number of authors. Adam *et al.* (2002) suggest that indicators based on price data dominate those based on quantities in terms of accuracy and moreover grant a clear-cut interpretation. Goldberg *et al.* (2003) state that real interest rate equalization is the broadest and most theoretically appealing measure of financial integration, as it refers to the law of one price. Baele *et al.* (2004) agree with such a claim, but advocate the use of nominal rather than real yields, motivating the choice by noting that otherwise one conducts a joint test of financial integration and purchasing power parity. In addition, local factors (like inflation) should not be relevant in integrated markets unless inflation is related to credit risk. I therefore used nominal interest rates as well.

I define financial integration as the Euclidean distance between the spread among long- and short-term interest rates reported by the OECD:

$$Fl_{ij} = \sqrt{(lir_i - lir_j)^2 + (sir_i - sir_j)^2},$$

where *lir* and *sir* are the long- and short-term interest rates, and *i* and *j* label different countries. This measure is based on the recognition that financial integration is a multi-faceted phenomenon, so that focusing on a single aspect (a single market segment) may produce a distorted picture. More specifically, different risk premia entail the presence of persistent spreads among government bond yields (and all long-term rates) also in presence of perfectly integrated capital markets: indeed, spreads may signal well functioning financial markets that are able to discriminate among different issuers. On the other hand, as the money market is more readily affected by the institutional changes brought about by EMU, short-term rates run the risk of presenting too strong an effect of monetary integration. This is because the emergence of a single reference rate for refinancing operations (that established by the ECB) generates a sort of ‘mechanical convergence’ in those market segments that are more heavily dependent on it. Using a combination of interest rates instead of a single one helps to limit the aforementioned effects and should provide one with a cleaner picture of capital market integration.

Similarity and specialization are computed from employment data for 27 sectors taken from the OECD *Stan* database. Sectoral similarity is measured as the sum over all sectors of the difference between the sector’s share on total employment in countries *i* and *j*:

$$S_{ij} = \sum_k |share_{ik} - share_{jk}|,$$

where *k* represents sectors. In addition, I built a measure for specialization given by the pairwise product of the Herfindahl indexes for the two economies.

Estimation of the system is performed using the error component 2SLS (EC2SLS) procedure suggested by Baltagi (2001). Despite the fact that 2SLS is a limited information method and therefore pays a price in terms of efficiency, in a Monte Carlo study Baltagi (1984) shows that the efficiency gain associated with EC3SLS is not large enough to justify the computational effort, while using the standard 3SLS estimator—which exploits all the available information, but disregards the panel structure of the data—yields inferior results.



## IV. EMPIRICAL EVIDENCE

Table 1 presents the correlation among relevant variables (boldface indicates significance at 5% level). The synchronization measure is that obtained using the band-pass filter. The signs of the coefficients support my maintained hypotheses (I measured *lack of* financial integration and structural similarity): there is a positive relation between trade and synchronization and between trade and financial integration. More important, the latter is positively related to GDP correlation.

Figure 1 provides some intuition of the phenomena under scrutiny by illustrating the developments of the relevant variables. Each panel distinguishes three groups of country-pairs: those in which both countries are (or later became) EMU members, those in which only one of them belongs to the EMU group; and those in which both countries belong to the rest of the world. Country-pairs are weighted by PPP-adjusted GDP to yield group averages, which are then plotted and displayed in the five panels.

TABLE 1  
PAIRWISE CORRELATION MATRIX<sup>a</sup>

	<i>synchr</i>	<i>trade</i>	<i>finance</i>	<i>struct</i>	<i>spec</i>
<i>synchr</i>	1.000				
<i>trade</i>	<b>0.241</b>	1.000			
<i>finance</i>	<b>-0.244</b>	<b>-0.262</b>	1.000		
<i>struct</i>	<b>-0.273</b>	<b>-0.389</b>	<b>0.298</b>	1.000	
<i>spec</i>	<b>-0.187</b>	<b>-0.175</b>	<b>0.140</b>	0.047	1.000

<sup>a</sup>Boldface indicates significance at 5%.

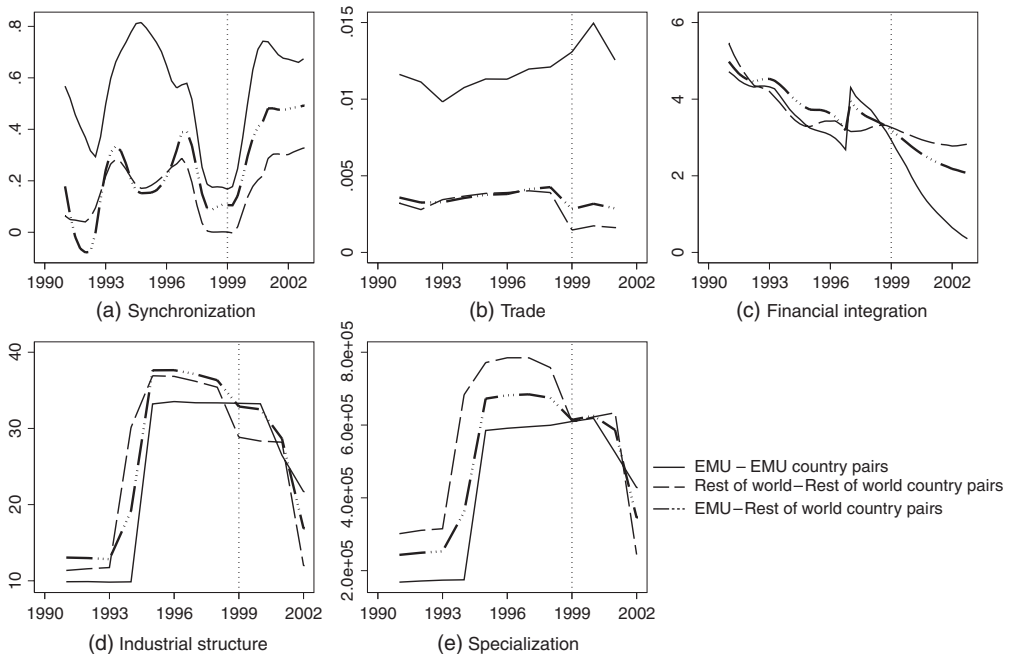


FIGURE 1. Synchronization, integration and industrial structure

Measures of business cycle correlation and trade integration are always larger for EMU members, witnessing to the long integration effort that predated monetary unification. More interestingly, and consistently with our focus on capital markets, financial integration appears to have increased very rapidly in EMU, starting just before the formal inception of the monetary union. Finally, EMU countries display on average a more similar industrial structure and are less specialized.

This pictorial evidence is confirmed by Table 2, which displays summary statistics. Comparing EMU members (panel *a*) with the rest of the sample (panel *b*), one can see that the former on average are more synchronized, experience larger trade flows and have smaller interest rate spreads. With respect to this last point, it is interesting to note that not only is the interest rate spread lower on average, but there is also much less variability (standard deviation drops from 2.55 to 0.61). The behaviour of specialization and structural similarity is less clear-cut: euro area countries seem to be slightly more similar and less specialized.

One may argue that the different behaviour of the two subsamples is the effect of a common worldwide trend rather than of the EMU in itself. Therefore panel (*c*) reports summary statistics for non-member countries limiting the analysis to the period 1999–2003. The resulting picture is qualitatively very similar to the previous one: interestingly, the case for a ‘euro effect’ seems even stronger. Output synchronization is the only variable for which the distinction between members and non-members of a currency union is smaller than in panel (*a*). On the contrary, for trade, finance, sectoral similarity and specialization, the difference grows larger. These results may be expected for trade and finance, as monetary unions are likely to involve large trading partners and/or economic systems that are already well integrated, while for what concerns similarity and specialization they stand witness against both the specialization hypothesis and the evidence proposed by Kalemli-Ozcan *et al.* (2001); in fact, EMU member countries

TABLE 2  
SUMMARY STATISTICS

Variable	Mean	Std. dev.	Min	Max	Obs.
<i>(a) CU = 1—period 1999–2003</i>					
<i>synchr</i>	0.6448	0.2541	0.1028	0.9629	45
<i>trade</i>	0.0112	0.0123	0.0007	0.0606	45
<i>finance</i>	0.4157	0.6107	0.0213	1.6987	45
<i>struct</i>	33.5542	9.4856	12.0050	53.8110	45
<i>spec</i>	615,232	65,001	525,850	794,230	45
<i>(b) CU = 0—period 1991–2003</i>					
<i>synchr</i>	0.2844	0.5305	– 0.9192	0.9934	525
<i>trade</i>	0.0047	0.0072	0.0000	0.0685	525
<i>finance</i>	3.3412	2.5494	0.1686	15.3690	506
<i>struct</i>	33.7565	9.7029	13.4070	60.2700	335
<i>spec</i>	682,440	92,374	454,270	906,230	335
<i>(c) CU = 0—period 1999–2003</i>					
<i>synchr</i>	0.4512	0.4213	– 0.6207	0.9934	145
<i>trade</i>	0.0030	0.0058	0.0000	0.0384	145
<i>finance</i>	2.3164	1.5853	0.3512	8.0958	145
<i>struct</i>	34.1257	10.5318	14.6580	58.4210	91
<i>spec</i>	720,809	72,392	592,570	892,240	91

display a markedly more similar economic structure and less specialization. All this lends credit to the endogeneity hypothesis.

### *Single-equation estimation*

Table 3 presents results for a set of bivariate regressions that investigate the impact of trade and financial integration, structural similarity and specialization on the correlation of business cycles. In this first stage the explanatory variables are introduced separately. Three different specifications are run for each control: (i) a simple bivariate regression, which is then augmented with (ii) a currency union dummy and, finally, (iii) a time trend. Results from bare-bones bivariate regressions (columns (1), (4), (7) and (10)) confirm my priors. Real and financial integration have a positive impact on output correlation, as does similarity of industrial structures; conversely, more specialized countries tend to be less synchronized. This evidence supports the idea that capital market integration fosters cycle correlation, contrary to what is customarily assumed.

In columns (2), (5), (8) and (11) a currency union dummy is added to the regression. While the estimated coefficients of the main variables are robust to this change, the behaviour of the currency union dummy is rather volatile: negative and not significant in the case of finance, it turns positive and significant in the other cases, moving to rather large numbers. This confirms the findings of Baxter and Kouparitsas (2004), i.e. that currency unions cannot be included among the robust determinants of business cycle correlation.

This last consideration is further corroborated when, to better evaluate the effect of EMU, a time trend is included (columns (3), (6), (9) and (12): the coefficient of the time trend is not shown). The coefficient of the currency union dummy loses significance in all instances, and becomes not statistically different from zero in the trade regression (column (3)). Estimated coefficients of other controls do not change.<sup>5</sup>

Before moving to multivariate analysis, I must emphasize that the lack of a direct relation between monetary integration and business cycle correlation does not work against my maintained hypothesis. The endogeneity argument does not in fact state that by joining a currency union a country will become more synchronized with its fellow countries, but rather that the likely increase in trade and financial integration brought about by the use of a single currency will have an effect also on output correlation. It is indeed this indirect effect that makes OCA endogenous.

The specification for multivariate regression analysis is the simple juxtaposition of all possible determinants of business cycle correlation encountered so far:

$$(5) \quad \text{synchr}_{ijt} = \alpha_0 + \alpha_1 \text{trade}_{ijt} + \alpha_2 \text{finance}_{ijt} + \alpha_3 \text{spec}_{ijt} + \alpha_4 \text{struct}_{ijt} + \alpha_5 \text{EMU}_{ijt} + \varepsilon_{ijt}.$$

Once again, I have used different specifications augmenting the basic regression equation with an EMU dummy, time dummies and a time trend. Results are summarized in Table 4 and largely confirm what bivariate regressions suggest: the currency union indicator is not robust to changes in the structure of the estimated equation, which implies that there is not a clear, *direct* link between the decision to use a single currency and output correlation. Its negative sign appears to confirm Farina and Tamborini's hypothesis, according to which, in the presence of structural asymmetries, monetary policy may have 'perverse effects' and lead to increased output dispersion.

Trade, finance and structural similarity have a positive impact on business cycle synchronization. The specialization measure (the pairwise product of the Herfindahl



TABLE 4  
MULTIVARIATE REGRESSIONS

	(1)	(2)	(3)	(4)
<i>trade</i>	0.170 (2.93)**	0.174 (3.00)**	0.272 (4.74)**	0.189 (3.24)**
<i>finance</i>	-0.385 (6.30)**	-0.430 (5.22)**	-0.281 (3.42)**	-0.372 (4.33)**
<i>spec</i>	-0.504 (0.95)	-0.526 (0.99)	-0.977 (1.86)	-0.815 (1.50)
<i>struct</i>	-0.615 (2.41)*	-0.570 (2.18)*	-0.411 (1.63)	-0.611 (2.35)*
<i>EMU</i>		-0.234 (0.81)	-0.755 (2.69)**	-0.366 (1.25)
Time dummies	No	No	Yes	No
Time trend	No	No	No	Yes
Observations	380	380	380	380
$R^2$	0.22	0.23	0.33	0.24

*Notes:*

Absolute value of *t*-statistics in parenthesis.

\*Significant at 5%; \*\*Significant at 1%.

Constant, trend and time trend not reported.

index) has the expected negative sign but is not significant at 5%. These conclusions are robust to the inclusion of period dummies and of a time trend (columns (3) and (4)).

Robustness is tested using alternative measures for cycle synchronization and financial integration, the two variables on which our attention is concentrated. Estimation results in Table 5 tell that what has been claimed so far does not hinge upon a particular way of measuring GDP linkages. Columns (1) and (2) are derived using bilateral correlations between the fourth differences of the log of real GDP, and results are very similar to those in Table 4. Even when I chose a radically different measure, such as the one proposed by Alesina *et al.* (2002) and used in columns (3) and (4), qualitative conclusions do not change.<sup>6</sup> If possible, these results are even more convincing, as all coefficients—apart from the EMU dummy—are significantly different from zero, have the expected sign, and therefore confirm our priors and agree with most of the existing literature.

In Table 6 I tested for the robustness of results to different measures of financial integration. First, in columns (1) and (2), I used lagged values of *F1* to account for potential endogeneity and found no significant difference. The effect of trade and finance is confirmed, while structural variables such as sectoral similarity and specialization lose significance.<sup>7</sup>

Next, I built a second measure of distance from the law of one price starting from government bond yields and bank lending rates: this index (*F2*) is appealing because the two rates span separate ('orthogonal') markets and therefore give a more complete picture of capital market integration.<sup>8</sup> As before, both trade and financial integration appear to exert a positive influence on output correlation; sectoral similarity and specialization lose significance although they display the correct sign; and the behaviour of the currency union dummy continues to be not robust to different specifications.

TABLE 5  
ROBUSTNESS: ALTERNATIVE SYNCHRONIZATION MEASURES

	4th quarter difference		AR(2) process	
	(1)	(2)	(3)	(4)
<i>trade</i>	0.155 (3.42)**	0.167 (3.66)**	-0.001 (2.57)*	-0.001 (3.69)**
<i>finance</i>	-0.373 (5.95)**	-0.325 (4.95)**	0.002 (4.69)**	0.001 (2.13)*
<i>struct</i>	-0.436 (2.14)*	-0.467 (2.29)*	0.002 (1.70)	0.003 (2.00)*
<i>spec</i>	0.422 (1.02)	0.183 (0.43)	-0.015 (5.22)**	-0.009 (3.36)**
<i>EMU</i>	-0.246 (1.13)	-0.339 (1.54)	0.002 (1.59)	0.004 (2.82)**
Time trend	No	Yes	No	Yes
Observations	380	380	380	380
R <sup>2</sup>	0.25	0.26	0.003	0.003

*Notes:*

Absolute value of *t*-statistics in parenthesis.

\*Significant at 5%; \*\*Significant at 1%.

Constant and trend not reported.

Although interest rate convergence has a clear-cut interpretation in terms of the law of one price, it may reflect a global phenomenon trend rather than a EMU-specific phenomenon. Therefore, in order to approach capital market integration from a different perspective, the last two columns of Table 6 report results obtained using a measure of financial integration based on the bilateral correlations of stock market returns.<sup>9</sup> Interestingly, capital market integration retains its positive effect on business cycle synchronization while other control variables are not affected.

At this point I can summarize a first set of results. My analysis points towards a robust effect of capital market integration on output correlation; this adds to the already established channel working through trade, whose existence and relevance is confirmed here as well. The role of structural similarity and specialization is less clear-cut, probably because these are slow-moving structural factors whose impact is difficult to distinguish at business cycle frequencies. Still, the intuition that more similar economies are hit by symmetric shocks and therefore display more correlated cycles, while economic systems that are very specialized tend to move less together finds some support. Regression results do not highlight any robust *direct* 'euro effect'. Consistent with what is reported by Baxter and Kouparitsas (2004), the coefficients of the currency union dummy are sensitive to different specifications, and even when significantly different from zero they change both sign and magnitude.

*System estimation*

To better address the role of EMU, I turn now to the simultaneous-equation framework first proposed by Imbs (2004), and capable of accounting for the interactions between key variables. This is particularly important in the present context, because my main

TABLE 6  
ROBUSTNESS: ALTERNATIVE FINANCIAL INTEGRATION MEASURES

	Lagged $F1$		$F2^\dagger$		Stock market corr.	
	(1)	(2)	(3)	(4)	(5)	(6)
<i>trade</i>	0.203 (3.37)**	0.225 (3.74)**	0.240 (2.91)**	0.294 (3.72)**	0.15 (2.27)*	0.201 (2.74)**
<i>finance</i>	-0.318 (3.47)**	-0.239 (2.51)*	-0.434 (3.38)**	-0.259 (2.04)*	0.809 (3.94)**	0.619 (2.63)**
<i>struct</i>	-0.331 (1.19)	-0.397 (1.43)	0.027 (0.06)	-0.357 (0.85)	0.252 (0.61)	0.368 (0.87)
<i>spec</i>	-0.795 (1.46)	-1.082 (1.97)*	-0.261 (0.35)	-0.987 (1.37)	-0.005 (0.04)	-0.047 (0.37)
<i>EMU</i>	0.581 (2.68)**	0.278 (1.15)	0.695 (2.35)*	0.034 (0.11)	0.685 (2.75)**	0.522 (1.95)
Time trend	No	Yes	No	Yes	No	Yes
Observations	363	363	205	205	347	347
$R^2$	0.18	0.20	0.20	0.28	0.19	0.19

Notes:

Absolute value of  $t$ -statistics in parenthesis.

\*Significant at 5%; \*\*Significant at 1%.

Constant and trend not reported.

$^\dagger F2 = \sqrt{(g_i - g_j)^2 + (b_i - b_j)^2}$ ,  $g$  government bond yield and  $b$  bank lending rate.

hypothesis entails an *indirect* effect of monetary unification on synchronization working through financial integration. The system allowed me to uncover such indirect effects, and therefore represents the most appropriate way to test the endogeneity hypothesis. For instance, we have seen above that economic theory does not unambiguously determine the impact of financial integration on GDP correlation. The simultaneous equations make it possible to see whether or not trade and financial integration really trigger specialization and thus drive economic systems further apart.

Table 7 displays results of EC2SLS estimation of the original system as specified in equations (1)–(4) above. A few minor modifications are needed to comply with the panel structure of our data-set and to match the priors of the paper. I introduce an EMU dummy in all the equations and instrument *finance* using its own lags. (The institutional variables used by Imbs (2004) are time invariant.) Results are similar to those reported in the original paper (Imbs 2004, table 4): in particular, trade and financial integration both affect output correlation positively, as does a similar industrial structure (though its coefficient is not significant). This in turn implies larger trade linkages and testifies to the importance of intra-industry trade. The main difference with Imbs's results lies in the sign (and significance) of the *finance* coefficient in column (3): I found no evidence for finance-induced specialization in different sectors. On the contrary, there seems to be a positive link between capital-market integration and similarity of industrial structures.

This last result offers support for the idea that greater/better access to international financial markets, by offering a wider range of risk-sharing instruments, allows countries to undertake similar patterns of specialization in risky, and therefore more financially demanding, activities.

TABLE 7  
SIMULTANEOUS EQUATIONS: IMBS SPECIFICATION

	(1) <i>synchr</i>	(2) <i>trade</i>	(3) <i>struct</i>
<i>trade</i>	0.203 (3.54)**		- 0.094 (6.11)**
<i>finance</i>	- 0.668 (4.60)**		0.066 (3.16)**
<i>struct</i>	- 0.216 (0.79)	- 2.632 (7.79)**	
<i>EMU</i>	- 0.82 (2.06)*	0.074 (1.13)	0.186 (3.20)**
Observations	363	380	363
$R^2$	0.18	0.76	0.25

*Notes:*

Equation-by-equation EC2SLS.

Absolute value of  $t$ -statistics in parenthesis.

\*Significant at 5%; \*\*Significant at 1%.

Constant and gravity variables not reported.

To better investigate this link, I slightly modify the structure of the system and explicitly distinguish specialization and structural similarity. Both Imbs (2004) and the vast majority of studies that deal with specialization patterns in Europe tend to assume that specialization necessarily implies less similar economic structure. This paper challenges that belief by adopting separate measures for specialization and structural similarity, as has already been done in the context of multivariate, single-equation estimation. Equation (5) thus becomes the first line in our modified system, where subscripts have been omitted for the sake of simplicity:

$$(6) \quad \textit{synchr} = \alpha_0 + \alpha_1 \textit{trade} + \alpha_2 \textit{finance} + \alpha_3 \textit{spec} + \alpha_4 \textit{struct} + \alpha_5 \textit{EMU} + \varepsilon_1$$

$$(7) \quad \textit{trade} = \beta_0 + \beta_1 \textit{finance} + \beta_2 \textit{spec} + \beta_3 \textit{struct} + \beta_4 \textit{EMU} + X_2 + \varepsilon_2$$

$$(8) \quad \textit{finance} = \gamma_0 + \gamma_1 \textit{trade} + \gamma_2 \textit{EMU} + X_3 + \varepsilon_3$$

$$(9) \quad \textit{spec} = \delta_0 + \delta_1 \textit{trade} + \delta_2 \textit{finance} + \delta_3 \textit{EMU} + X_4 + \varepsilon_4$$

$$(10) \quad \textit{struct} = \phi_0 + \phi_1 \textit{finance} + \phi_2 \textit{spec} + \phi_3 \textit{EMU} + \varepsilon_5.$$

Equation (7) postulates that trade is explained by finance (trade credit offers a simple justification for this), specialization and sectoral similarity, which command inter- and intra-industry trade, respectively.  $X_2$  is a set of exogenous determinants containing gravity variables (GDP, distance, common language and number of landlocked countries in the pair: these data are taken from Andrew Rose's website). Financial integration depends on trade linkages (equation (8)): the rationale behind this idea is the model presented in Obstfeld and Rogoff (2000), where the authors show how small frictions in goods markets may explain some of the most relevant 'puzzles' in the functioning of international capital markets. The predetermined variables  $X_3$  are *finance* own-lags. Equation (9) replicates Imbs's (2004) specification and states that sectoral specialization



is driven by trade and financial integration plus the pairwise product and ratio of GDP per capita. (The latter two controls are subsumed by  $X_4$ .) The last equation establishes a link between specialization and similarity of industrial structures and therefore formalizes the hypothesis that specialization may occur in similar sectors.

Exogenous determinants included in  $X_2 - X_4$  serve the double purpose of identifying the system and tackling the simultaneous-equation bias arising from the use of endogenous regressors. Hence, whenever one of the five left-hand-side variables enters the system as a regressor—like *trade* in equations (6), (8) or (10)—it is instrumented by its exogenous determinants (gravity variables, in the case of trade).

Each column of Table 8 represents one equation of the system, while relevant controls are on rows (exogenous determinants are not reported). Column (1) confirms results of multivariate regression analysis (Tables 4–6 above) and therefore does not require a detailed discussion: let me note that the coefficient of structural similarity loses significance but keeps the expected sign (low values of *struct* are associated with higher correlation), while specialization is again negative but not significant. The EMU dummy is negative, rather large and significant: I interpret this as confirming the existence of ‘perverse effects’ of the common monetary policy *à la* Farina and Tamborini (2004).

Estimation of equation (7) yields the results reported in column (2): the currency union dummy as well as gravity variables (not shown) have the expected sign; both sectoral specialization and structural diversity have a negative sign, which suggests the prevalence of intra-industry over inter-industry trade. These estimated coefficients in fact tell us that more specialized countries tend to trade less—while, conversely, economies with a similar industrial structure enjoy large commercial flows. Financial integration appears not to play a relevant role in determining trade linkages, but this is little wonder as the latter usually predate the former.

Column (3) confirms my intuition and suggests both that EMU has had a relevant impact on financial integration inside the euro area, and that trade relations facilitate capital market harmonization.<sup>10</sup>

Results for equation (9) yield contrasting signals: while in fact there is no sign of trade-induced specialization—on the contrary, deeper commercial links are associated with lower values for the product of Herfindahl indexes—financial integration seems to enhance specialization, as has been documented in Kalemli-Ozcan *et al.* (2003).

Equation (10) should tell us whether the specialization triggered by international capital market integration occurs in similar (risky) sectors or results in countries having less similar industrial structures. Estimates in column (5) seem to support the idea that countries specialize in similar sectors; in fact, more specialization is associated with lower structural diversity. Yet the very low value of the  $R^2$  (very low even for the standards of panel regression models) suggests caution when interpreting these results.

The second set of results reported in Table 8 has been obtained using sectoral stock market capitalization data to compute specialization and structural similarity; furthermore, I refer to stock market correlation when measuring financial integration.<sup>11</sup> This latter change implies that the expected sign of the coefficient for *finance* is now positive.

Estimated coefficients for trade and financial integration in equation (6) are in line with my maintained hypothesis. Structural variables change sign, but remain not significantly different from zero. The same applies to the EMU dummy, which becomes positive and not significant. The impression that specialization, similarity of industrial structures and monetary integration do not have a clear-cut, direct effect on synchronization is therefore confirmed.

TABLE 8  
SIMULTANEOUS EQUATIONS: INSTRUMENTAL VARIABLE (EC2SLS) Estimation

	Sectoral employment and FI					Sectoral market value and stock market correlation				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	<i>synchr</i>	<i>trade</i>	<i>finance</i>	<i>spec</i>	<i>struct</i>	<i>synchr</i>	<i>trade</i>	<i>finance</i>	<i>spec</i>	<i>struct</i>
<i>trade</i>	0.187 (3.08)**		-0.046 (2.14)*	-0.037 (4.53)**		0.253 (2.87)**		0.082 (6.00)**	-0.002 (0.04)	
<i>finance</i>	-0.689 (4.87)**	0.110 (1.15)		-0.027 (2.14)*		0.867 (2.65)**	0.666 (4.01)**		-0.657 (5.20)**	
<i>struct</i>	-0.243 (0.86)	-1.101 (4.74)**				0.448 (1.12)	1.256 (4.03)**			
<i>spec</i>	-0.353 (0.64)	-4.479 (6.00)**			-0.512 (3.22)**	0.101 (0.84)	-1.694 (11.32)**			-0.046 (0.81)
<i>EMU</i>	-0.888 (2.28)*	0.570 (2.22)*	-2.248 (21.13)**	-0.020 (0.56)	0.011 (0.79)	0.374 (1.42)	0.334 (2.75)**	0.142 (2.63)**	0.472 (4.92)**	-0.087 (2.24)*
Observations	363	363	532	363	380	397	397	485	397	459
R <sup>2</sup>	0.18	0.62	0.66	0.10	<0.01	0.22	0.63	0.44	0.19	0.10

Notes:

Absolute value of *t*-statistics in parenthesis.

\*Significant at 5%; \*\*Significant at 1%.

Constant and exogenous controls not reported.

One observes some relevant changes in column (2): first, the coefficient of financial integration becomes significantly different from zero and therefore establishes a link between this variable and trade flows; second, structural similarity changes sign and turns positive, suggesting that more diverse economic systems tend to have closer commercial contacts. This reverses my previous result and can be explained by Ricardian trade theory and comparative advantages.

Results in column (8) are qualitatively equal to those obtained previously. Moving to equation (9), any sign of finance-induced specialization disappears as this time financial integration exerts a negative effect on specialization. This change in the behaviour of variables connected with the structure of the economy is confirmed in column (10), where the effect of specialization on the similarity of economic structures becomes not significantly different from zero. Interestingly, though, the behaviour of the EMU dummy in the last two columns of the table supports the idea that monetary integration makes countries more similar as well as more specialized.

To summarize, results from the simultaneous equation approach confirm the existence of an endogenous effect linking the use of a single currency with the synchronization of business cycles and working through capital market integration. This indirect effect is given by  $[\gamma_2 \cdot \alpha_2]$  and makes the pair with the trade channel identified by Frankel and Rose (1998), which amounts to  $[\beta_4 \cdot \alpha_1]$ .<sup>12</sup> Our estimates imply that, starting from the mean values for the EMU group before 1999, reducing *F1* by 50% results in an increase in output correlation of 0.10.

I was less successful in determining the relation between financial integration and sectoral dynamics. Data and empirical analysis do not in fact offer a clear-cut picture of the relation between the adoption of a single currency, capital market integration and sectoral specialization patterns.

## V. CONCLUSIONS

In this paper I have investigated the relation between financial integration and output correlation in the context of OCA theory. I found robust and consistent evidence that monetary integration enhances capital market integration, which in turn feeds back into the system and results in closer business cycle synchronization. This mechanism adds to the trade channel highlighted by Frankel and Rose (1998), lends credit to the hypothesis that countries are better candidates to join a monetary union *ex post* rather than *ex ante*, and represents the main contribution of the paper.

More work is needed to understand fully the determinants of the relation between these two variables. One possibility—the hypothesis that capital market integration triggers specialization in similar sectors—finds some support in the data, but empirical evidence is far from conclusive.

The implication of these findings for European policy-making are important and far-reaching. The debate on the pros and cons of EMU participation, especially in opt-out countries and new EU members, obviously benefits from a wider and deeper understanding of the forces set in motion by monetary integration. Moreover, the emphasis placed by European institutions on the harmonization and integration of goods and capital markets seems well placed. In fact, through its effects on the co-movement of macroeconomic variables, closer integration is not only beneficial to consumers, but may also facilitate the task of euro area policy-makers.

## APPENDIX

Measures of output synchronization based on bilateral correlation are transformed before entering the regression analysis. This is done to account for the fact that sample correlations must lie between  $-1$  and  $1$ , while independent variables span the whole real line. This is likely to have adverse effects in the estimation of a model of the form

$$(A1) \quad \rho = \alpha \log(x) + \varepsilon.$$

This problem is first recognized by Otto *et al.* (2001), which—to my knowledge—remains the only work to tackle the issue.

Following the transformation proposed there, the dependent variable becomes

$$(A2) \quad \tilde{\rho} = \log\left(\frac{\rho + 1}{1 - \rho}\right);$$

$\tilde{\rho}$  now spans the whole real line and the transformed model is

$$(A3) \quad \tilde{\rho} = \alpha \log(x) + \varepsilon.$$

As a result of the transformation, the interpretation of the coefficients changes slightly: while equation (A3) implies that a 100% increase in  $x$  results in a change in  $\tilde{\rho}$  equal to  $[\alpha \log(2)]$ , the impact on  $\rho$  has a slightly more complex formulation.

Given my interest in the effect of financial integration and the fact that  $Fl_{iji}$  measures distance from the law of one price, I analyzed the case in which the explanatory variable  $x$  drops from  $x_1$  to  $x_2 = x_1/2$ . Combining equations (A2) and (A3) and abstracting from the error term, we have

$$(A4) \quad \tilde{\rho}_1 = \log\left(\frac{\rho_1 + 1}{1 - \rho_1}\right) = \alpha \log(x_1) = \log(x_1^\alpha)$$

$$(A5) \quad \rho_1 + 1 = x_1^\alpha - \rho_1 x_1^\alpha$$

$$(A6) \quad \rho_1 = \frac{x_1^\alpha - 1}{1 + x_1^\alpha}.$$

Doing the same for  $x_2$  yields a similar expression for  $\rho_2$ :

$$(A7) \quad \rho_2 = \frac{x_2^\alpha - 1}{1 + x_2^\alpha} = \frac{x_1^\alpha - 2^\alpha}{x_1^\alpha + 2^\alpha}.$$

At this point, by subtracting (A6) from (A7) we obtain the variation in  $\rho$  resulting from a 100% change in  $x$ :

$$(A8) \quad \Delta\rho = \frac{x_1^\alpha - 2^\alpha}{x_1^\alpha + 2^\alpha} - \frac{x_1^\alpha - 1}{1 + x_1^\alpha} = \frac{2x_1^\alpha(1 - 2^\alpha)}{(2^\alpha + x_1^\alpha)(1 + x_1^\alpha)}.$$

## ACKNOWLEDGMENTS

I would like to thank Jacques Le Cacheux, Axel Leijonhufvud, Roberto Tamborini, Maria Luigia Segnana and two anonymous referees for useful comments and suggestions. None of them can be blamed for any remaining mistake, however.

## NOTES

1. This argument implies that the similarity of shocks should no longer be a prerequisite for sharing a single currency, as long as agents are insured through private financial markets. Recent empirical studies however, point to negligible risk-sharing achieved through this channel (Tesar 1995; Sørensen and Yosha 2000).
2. A single central bank in charge of monetary policy coupled with national fiscal authorities that face binding deficit ceilings.

3. One of the key assumptions underlying Farina and Tamborini's result is that automatic stabilizers cannot completely offset the impact of a shock. Such an occurrence would be magnified in the event that the existence of persistent regional disparities calls for substantial public intervention, absorbs a relevant share of national budget expenditures and, in the presence of binding deficit limits, ends up reducing the amount of resources available for stabilization purposes.
4. Countries included in the sample are Australia, Austria, Belgium–Luxembourg, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.
5. When the time trend is substituted by period dummies, estimated coefficients of controls do not display any significant change, while the EMU dummy becomes not significant in all regressions. These results are not reported.
6. That is an index of distance between the innovations from an AR(2) process fitted to real GDP series: it measures lack of co-movement and therefore implies that the sign of coefficient must change with respect to the previous cases.
7. Imbs (2004)—who uses quantity-based measures of financial integration—suggests that financial flows may be larger between less synchronized markets as this would allow for better risk-sharing. Although this source of endogeneity works *against* my maintained hypothesis, and although it does not have an immediate translation to the case of price-based measures, I prefer not to leave the question unaddressed.
8. The lending rate is the *prime rate* reported by Datastream.
9. In truth, there is no compelling reason why financially integrated economies display correlated stock market returns. Adam *et al.* (2002) note that this indicator tends to be unstable in the short run and that *ex post* return correlations have a questionable economic interpretation. Furthermore, this measure may reflect changes in the structure of real and policy shocks. None the less, despite these limitations, it finds widespread use in the literature.
10. EC2SLS is ill suited to deal with the presence of lagged dependent variables among the regressors in equation (8). The appropriate econometric machinery is a dynamic panel setup enabling one to deal with both endogenous controls and lagged dependent variables (Bond 2002). Luckily enough, the two methodologies yield very similar results; therefore, for the sake of simplicity, Table 8 reports only EC2SLS estimates, while the other results are available upon request.
11. Sectoral data are taken from Datastream and comprise 35 sectoral stock market indexes: the similarity and specialization measures are derived from the share of each sectoral index over total stock market capitalization. On the one hand, this data-set presents fewer missing observations and a finer classification which divides the economy in a larger number of sectors. On the other, stock market capitalization is traditionally skewed toward sectors dominated by higher returns of scale and hence large firms; moreover, the FTSE Global Classification System employed by Datastream gives a rather high weight to service-based sectors whose activities entail a (more or less large) non-tradable component.
12. The overall EMU effect would be given by  $\alpha_5 + \gamma_2 \cdot \alpha_2 + \beta_4 \cdot \alpha_1 + \delta_3 \cdot \alpha_3 + \phi_2 \cdot \alpha_2$ .

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