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Twenty years with the Euro: Eurozone banking market integration revisited

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ABSTRACT

Banking market integration is essential for a stable European Monetary Union but was severely disrupted during the Eurozone crisis. With heterogeneous national banking markets, interpreting the recent post-crisis convergence of national interest rates as restored integration has been challenged in the literature. We therefore scrutinize integration under the condition of market heterogeneity for 12 Eurozone countries before, during and after the Eurozone crisis from 2003 to 2019, employing a novel combination of state-of-the-art network analyses and estimates of bilateral interest rate linkages. We measure integration as bi-directional (Granger) causality relations between lending rates or margins in order to identify crisis-resilient arbitrage mechanisms. Their extent, disruption and restoration inform our subsequent network analysis, which unveils that the Eurozone crisis has fundamentally and persistently disrupted this network beyond the crisis period even when interest rates and margins are converging. Our approach complements and extends existing integration analyses by revealing policy-relevant but otherwise undetected disintegration.

1. Introduction

In 1999, the single European currency was introduced in 11 countries which, surprisingly, paid little attention to the state of integration of their banking markets, which would henceforth carry out all financial cross-border transactions in the Eurozone in Euros. The Maastricht Treaty formulated the conditions for joining the European Monetary Union (EMU), but none of them was related to banking markets.[1] More surprisingly, little was known about the state of European banking market integration at the time.[2] In 1999, hopes were pinned on the creation of the single currency to boost financial integration. Tommaso Padoa-Schioppa (2000) from the board of the European Central Bank (ECB) argued at the time that the 'multiplicity of currencies in the single market was a fundamental factor behind the preservation of the segmentation of the banking industry' and 'it is indeed the existence of a single currency and a single central bank which very often unifies a banking system'.

Today, after the common currency's near-death experience during the Euro crisis, there is a broad consensus that a crisis-resilient single currency needs to be complemented by a single banking market (Bénassy-Quéré et al., 2018). Hence, the state of European banking market integration is reviewed on a recurrent basis, most importantly by the ECB's regular reports on 'Financial Integration in Europe'. However, the devil is in the detail, in particular when measuring "deep" banking market integration that makes the single currency more crisis resilient.

What then characterizes a deeply integrated banking market? Early on, Adam et al. (2002), commissioned by the European Union, developed and applied methods to report on financial integration. Their benchmark is the law of one price (LOOP). Hence, cross-country correlations and dispersion of interest rates became the metrics of choice to document

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[1] As entry conditions, the Maastricht Treaty requires exchange rate stability, fiscal deficit and public debt limits, inflation convergence and interest rate convergence for long-term government bonds denominated in national currencies.

[2] Early academic literature is sparse and consists of Steinherr and Huveneers (1992), Zimmerman (1995), Lemmen (1998), Centeno and Mello (1999), Kleimeier and Sander (2000) and Buch (2002).

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integration. While these are meaningful concepts for equity and bonds markets,[3] bank interest rate equalization can be misleading in heterogeneous banking markets when underlying lending risks in member countries differ (Dermine, 2006). In particular, interest rate parity and convergence on the way to parity could simply reflect an interest-rate pass-through from a single policy rate via money market rates to bank interest rates. In fact, interbank markets integrated rapidly after 1999, while deep integration, understood as bank-to-real-sector cross-country flows as well as cross-border bank consolidation, remained limited (ECB, 2018; Angeloni, 2020). Unfortunately, this shallow integration via money markets in the presence of a single monetary policy has proven to be highly pro-cyclical and prone to sudden stops when Eurozone money markets disintegrated during the crisis.

In this paper we investigate the development of deep banking market integration in the Eurozone, understood as the existence of sustainable and crisis-resilient arbitrage mechanisms in cross-border banking, before during and after the Eurozone crisis. To this end we implement a novel combination of state-of-the-art network analyses and estimates of Granger-causal bilateral linkages for heterogeneous banking markets. We apply this methodology to prices in retail banking markets, e.g., lending rates and margins. Our paper extends the existing literature in three major ways. First, we advance the literature on banking market integration measures (section 2) by introducing a measure of bilateral arbitrage processes which is able to distinguish shallow from deep integration (section 3). Second and to the best of our knowledge, we are the first who provide a causality-based banking market integration measure that is able to determine the direction of the arbitrage processes. This, third and foremost, informs our novel network analysis with price-based measures of deep and shallow banking market integration (section 4). We scrutinize bilateral banking market integration for all pairs of the original 11 EMU member countries plus Greece during the period of January 2003 to June 2019 over carefully defined per-crisis, crisis, and post-crisis periods (section 5). Our results (section 6) are presented using network analysis measures to document the disruptive influence of the Eurozone crisis on banking market integration. We find that the recent rebound in correlations of national bank interest rates should not be misread as an emergence of a deep European banking network. In fact, we show that the damage done by the Eurozone crisis to this network is long-lasting and persistent. In conclusion (section 7), our results lend support to the view that creating a full banking union is vital for achieving deep Eurozone banking market integration.

2. The importance of deep banking market integration

The seminal paper by Robert Mundell (1961) stresses the importance of synchronized business cycles for the smooth functioning of a monetary union with a single monetary policy. Should, however, asymmetric shocks occur that hit some but not all countries of a single currency area, some form of risk-sharing is needed to compensate for the lack of monetary autonomy. One policy option is public risk-sharing via financial transfers amongst member countries. Yet, the sovereign debt crisis in the Eurozone has forcefully demonstrated the resistance of member countries to cross-border fiscal transfers, let alone to a fiscal union. Private risk-sharing through financial markets is the alternative. As Mario Draghi (2014) pointed out: 'In a monetary union like ours, there is a particular onus on private risk-sharing to play this role. Indeed, the less public risk-sharing we want, the more private risk-sharing we need'.

2.1. Private risk-sharing through financial integration

Private risk-sharing can be provided by financial market integration that allows for diversified portfolios containing assets from all member countries.[4] Consider equity and bond markets: if one country is hit by a negative shock and the other one not, then the value of assets will fall in the first country. If portfolios are sufficiently diversified across countries, this asymmetric shock is less severe for asset holders in the negatively affected country and dispersed across asset holders of all member countries. Likewise, a positive shock to one country benefits asset holders of all member countries. Hence, this form of private risk-sharing promotes consumption smoothing across member countries in the presence of asymmetric shocks. However, this consumption smoothing is mainly benefitting equity and bond holders.

Thus, banking market integration is of particular importance to smooth out the effects of asymmetric shocks. Consider, for example, that France experiences an idiosyncratic demand shock that leads to a recession in France but not in other Eurozone countries. Increased cross-border lending from banks in unaffected countries to French borrowers could help stabilize GDP and/or consumption in France. For such income and consumption smoothing to happen, some form of cross-border arbitrage by banks in search of higher foreign lending margins should take place. If banks are present in all member countries, either via subsidiaries and branches or via cross-border lending and borrowing, banks hit by an asymmetric shock in one country can compensate their losses, e.g., non-performing loans with better financial results in unaffected countries. A more steady flow of credit can smooth the effects of asymmetric shocks and provide a more stable banking system in each member country of a currency union (De Grauwe, 2014). Based on a comparative analysis of various forms of financial risk-sharing, Fecht et al. (2007) argue in favor of retail banking market integration. However, these beneficial effects depend on three major conditions: first, markets are efficient enough so that portfolios of investors or banks can be sufficiently diversified. Second, regulatory differences that inhibit diversification are removed. Third, the elimination of exchange rate risk via the common currency is fully credible.

2.2. Evidence on private risk-sharing and financial integration in the European Monetary Union

In the run-up to the EMU scholars intensively revisited the literature on common currency areas, largely based on Robert Mundell's seminal paper and subsequent scholarly works (Mundell, 1961; McKinnon, 1963; Kenen, 1969). The empirical corollary to this work is to identify the presence and importance of asymmetric shocks within a currency union. The influential paper by Bayoumi and Eichengreen (1993) identifies two subgroups amongst the original proposed 11 EMU member countries: a "core Europe" of Northern member countries and a "Club Med" of Southern member countries. While this suggests that including non-core countries in the monetary union could potentially cause problems, the authors recognize that the switch to a common currency could ultimately lead to more synchronized business cycles. The reason is that the documented asymmetries were largely caused by aggregate demand shocks that might eventually be mitigated once a common monetary policy is in place. When revisiting their earlier research 25 years later and extending their data to 2014, Bayoumi and Eichengreen (2020) find that the distinction between core and periphery has persisted but with a surprisingly different core group, comprising Germany as well as Greece, Ireland, Italy, Portugal and Spain, the so-called GIIPS countries. The authors suggest that this result 'may reflect distortions in operation of the monetary union as much as underlying integration'.

Hence, there is an emerging consensus that banking market integration is crucial for the stability and sustainability of the EMU, in particular because of its role in private (consumption) risk-sharing. According to the ECB (2018), risk-sharing is still low and shocks are largely unsmoothed.

[3] Răileanu-Szeles and Albu (2015), for example, analyze the convergence dynamics of European bond yields and identify convergence clubs at the time of the Global Financial Crisis.

[4] Mundell (1973) originally made this point, commonly known as "Mundell II". McKinnon (2004) discusses Mundell I versus Mundell II.

Most strikingly, the ECB documents a partly positive contribution of the credit channel to consumption risk-sharing between 2002 and 2006. Since 2007, however, the credit channel's contribution is negative, indicating that the credit channel is now intensifying rather than dampening consumptions shocks.[5]

In a similar vein, Hoffmann et al. (2019) find a substantial decrease in risk-sharing after the Global Financial Crisis (GFC) and, in particular, after the Euro crisis that started in 2010 with the Greek sovereign debt crisis. A key reason is that banking market integration has been shallow in the sense that it concentrated on a full integration of interbank markets while deep integration via cross-border retail banking has remained largely absent. The authors find that unlike an indirect integration via interbank flows, which have proven very pro-cyclical during crises, direct banking integration allows for significant risk-sharing, predominantly by means of income smoothing. The authors argue further that disrupted interbank flows were largely responsible for the unfavorable turnaround in consumption smoothing of households and consequently contributed to the breakdown in risk-sharing. In their view, the unbalanced reliance of indirect rather that deep integration of banking markets has been the major factor that interrupted risk-sharing in the Eurozone after the GFC.

Recently, Imbs and Pauwels (2019) document that financial deregulation (measured as the number of Financial Service Action Plan directives implemented at the country level) positively contributed to risk-sharing before the GFC and negatively afterwards. In a comment on their paper, Kalemli-Özcan (2019, p. 82) cautions 'that financial integration helped consumption smoothing tremendously both before and during crisis, but there is a different role for cross-border liabilities and assets, where liabilities can hurt and assets can help smoothing'.

The key takeaway from this discussion is that real or deep banking market integration has remained too low. The often-reported integration progress based on cross-country bank interest rate convergence is just a statistical mirage. It is the result of a common monetary policy and money market integration under the condition of an unchanged interest-rate pass-through to bank rates. The moment money market integration was disrupted by the GFC, it became clear that emperor was without clothes.

3. A theoretical framework for investigating deep banking market integration

3.1. A short conceptual overview

Reporting on financial integration in the Eurozone often follows Baele et al.'s (2004) taxonomy of quantity-based, price-based and new-based measures.

Quantity-based measures report the actual flow of cross-border bank loans and deposits and cross-border banking consolidation. The message here is that real banking market integration is of relatively low importance and has not yet fully recovered from the disruptions of the crisis. The ECB (2018, p. 32) concludes in its Financial Integration Report that 'Quantity-based indicators continued to signal limited retail banking integration, either through the cross-border provision of services or the establishment of local units'.

Price-based measures report metrics based on interest rates, typically cross-country correlations derived from the LOOP, and thus complement quantity-based indicators. In the run-up to the EMU, interest rates converged not only in bond and money markets but also in retail banking markets. After the introduction of the Euro as legal tender, almost all retail lending and deposit rates showed a strong tendency of co-movements, although with varying degrees. However, these co-movements signaled only shallow integration as various cointegration studies have documented (Centeno and Mello, 1999; Kleimeier and Sander, 2000, 2007; Schüler and Heinemann, 2003; Brada et al., 2005; Rughoo and Sarantis, 2014; Gupta and Seghal, 2019). During the hot phase of the Euro crisis from 2010 to 2012, the cross-country dispersion of these rates increased dramatically and only gradually declined after Mario Draghi's "whatever-it-takes" speech and the adoption of the ECB's non-standard monetary policy measures. As the degree of integration increases with the retail market's competitiveness, several studies use intermediation margins to investigate banking market competition and contestability instead of using retail interest rates to detect integration (Corvoisier and Gropp, 2002; Gropp et al., 2014). The idea is that in integrated markets, differences in margins should lead to cross-border arbitrage. Hence, banking markets are integrated when margins are cointegrated.

News-based measures exploit the idea that under the conditions of full financial integration asset prices should mainly react to common news. In retail banking markets, these common news are either policy or money market rate changes to which bank interest rates are expected to react in a uniform way. Before the GFC, this interest-rate pass-through process had indeed become more uniform (Sander and Kleimeier, 2004; De Bondt et al., 2005; Kwapil and Scharler, 2010). Hence, the integration of the interbank market helped retail bank rates across Eurozone countries to move in tandem. Since the GFC, the dispersion of bank interest rates has increased due to the disintegration of the money markets – which additionally lost their function of short-term funding for banks – and a distortion of the pass-through process itself as argued by Aristei and Gallo (2014) and Hristov et al. (2014). However, von Borstel et al. (2016) argue that it is not the transmission of monetary policy to bank lending rates but the composition of the pass-through that has changed with the crisis. Their results suggest that the adoption of non-traditional monetary policy measures by the ECB contributed to a partial restoration of the pass-through, which explains the gradual increase in retail rate co-movements after the Eurozone crisis.

From this discussion we conclude that all three types of measures are important and complementary.[6] Yet, price-based indicators that focus on interest rate convergence occasionally contradict the quantity-based evidence. Hence, we focus on causality measures for heterogeneous markets to document deep integration not only for retail interest rates but also for intermediation margins as a valuable source of information on integrative arbitrage processes.

3.2. Arbitrage as deep banking market integration

We understand deep banking market integration as the existence of sustainable and crisis-resilient international arbitrage mechanisms in cross-border banking. One can differentiate four distinct arbitrage mechanisms. First, banks supply cross-border loans to foreign markets. Second, customers borrow abroad. Third, banks enter foreign markets and offer loans through local branches or subsidiaries. Fourth, arbitrage takes place in funding markets via cross-border deposit flows from customers to banks.

Arbitrage can be studied by directly looking at quantities such as the cross-border loans, deposits and cross-border investments or by indirectly looking at price differentials across these cross-border loans, deposits and investments. The quantity-based approach has the advantage of being able to identify major drivers of arbitrage processes. For example, Niepmann (2015) uses trade-theory inspired gravity models to explain different arbitrage channels in lending. In her model transaction costs limit arbitrage, while large differences in returns drive "international banking" understood as cross-border lending. Differences in efficiency are found to promote "global banking", understood as raising capital and investing capital abroad, whereas "foreign funding", understood as domestic banks tapping into foreign funding markets, is driven

[5] See Chart 2 in ECB (2018, p. 14).

[6] For a recent study that combines quantity-, price- and news-based measures into a single analysis to investigate financial integration versus fragmentation in the euro area, see Arce-Alfaro and Blagov (2022).

by capital scarcity in the domestic economy.[7] In contrast, the price-based approach cannot identify the drivers of arbitrage but visualizes prices, e.g., interest rates, as the outcomes of the underlying arbitrage processes. Thus, the price-based approach assumes that interest rate differentials across countries already reflect the differences in national arbitrage drivers, depending on the actual degree of capital mobility. However, quantity-based measures have the disadvantage that they wrongly signal less integration the more prices converge and incentives for further arbitrage decrease. The limiting case is defined by a situation in which effective arbitrage has already taken place or markets are open and contestable. In the latter case, the threat of entering a market can already be sufficient to integrate banking markets without any arbitrage taking place. We therefore propose a price-based approach that can differentiate between deep and shallow integration.

When using price-based metrics to document deep banking market integration, we postulate that cross-border arbitrage processes can ultimately move prices towards *perfect integration*. The theoretical benchmark for perfect integration in financial markets is the interest rate parity condition, which should hold in absence of all regulatory and institutional barriers, aka, full capital mobility. Interest rate equalization, however, additionally requires homogeneous and thus fully substitutable assets and liabilities (loans and deposits) across all jurisdictions. Full capital mobility and perfect substitutionability are therefore requirements for *perfect integration*.[8] As retail banking products differ considerably across borders in terms of demand, preferences, risk, regulation, taxation, etc., full integration in heterogeneous banking markets is fully compatible with differences in interest rates. Hence, the LOOP is neither a necessary nor a sufficient condition for *full integration*.

Eq. (1) presents a very simple bilateral version of the interest rate parity for national lending rates (L) of heterogeneous loans, where * denotes the partner country:

$$L_t = a + bL_t^* \tag{1}$$

In an integrated banking market, higher lending rates abroad should encourage arbitrage processes via cross-border borrowing by customers or cross-border lending by banks. Full integration is signified by coefficient b taking a value of 1. It reflects complete arbitrage in the absence of frictions in cross-border banking, such as transaction costs. However, complete arbitrage processes must not – and should not even – lead to full interest rate equalization across markets characterized by different idiosyncratic risks, as measured by the intercept a. Eq. (1) can thus be considered as a long-term equilibrium relationship between lending rates of any pair of countries given the heterogeneity of loans and the degree of integration. The existence of (fully or partially) integrated markets can be detected with cointegration methodologies when short-term deviations from the long-run relationship are corrected by arbitrage processes. This is our definition of deep integration.

Unlike simple correlation metrics, our approach relies on arbitrage processes to indicate deep integration, rather than co-movements of interest rates. The latter can occur when the pass-through of changes in money market rates onto lending rates is uniform across countries. If the pass-through coefficient is equal across all countries in a monetary union, then changes in money market rates (as proxies for the common monetary policy stance) lead to similar changes in lending rates, thus producing the cross-country correlations that are often wrongly interpreted as banking market integration.[9] Instead, these correlations simply show that a uniform pass-through process has been established – or re-established after a crisis by means of non-standard monetary policies as argued by ECB (2018). Hence, integration measured by correlations is shallow and can be distorted by disruptions in the interest-rate pass--through. In our approach, as long as interest rates diverge from the long-term equilibrium defined in Eq. (1), which is basically always the case in the data, this incentivizes arbitrage processes that we investigate to test for deep integration.[10]

Convergence in funding rates, whether caused by cross-border arbitrage in deposit markets or by a common (unconventional) monetary policy, can align lending rates and we thus cross-check for deep integration by investigating intermediation margins. Especially when cross-border lending and borrowing are low, intermediation margins and, hence, banking market profitability can differ and thus provide an incentive for banks to cross borders via foreign branches and subsidiaries or cross-border acquisitions. Thus, not only lending rates but also lending margins are informative about deep integration.

Banks typically base loan rates on their (marginal) funding costs (F). The actual costs of funds depend on the funding sources, which prior to the GFC were mainly non-bank deposits.[11] Hence, average deposit rates reflect funding costs and co-determine intermediation margins and bank profitability, which should induce arbitrage processes in an integrated banking market. This arbitrage process can be monitored by investigating the empirical relationship between intermediation margins:

$$(L_t - F_t) = c + d\left(L_t^* - F_t^*\right) \tag{2}$$

In case of a complete arbitrage process ($d = 1$), margins only differ due to differences in idiosyncratic country risk c. If this risk is merely reflecting differences in funding costs – in which case c will be equal to the difference between F and F* – lending rates will equalize too. If not, differences in lending rates can prevail despite a complete arbitrage process as the differences in deposit rates are not reflecting differences in idiosyncratic risk but in market power.

Jointly, Eqs. (1) and (2) provide some simple but key insights into the effects of full arbitrage processes, i.e., when b in Eq. (1) and d in Eq. (2) are equal to one. This immediately yields that the differences in funding costs F–F^* must be equal to a-c. Four insights can be obtained from this: first, if additionally loans are perfect substitutes across countries, then a will take the value of zero and differences in the mark-up will be equal to differences in funding costs. Second, if, alternatively, intermediation margin converge, differences in loan rates must be equal to differences in funding costs. Third, if funding rates converge, then loan rate differences a will be equal to differences in mark-ups c. Forth and for completeness, with a and c both equal to zero and full integration, the LOOP holds in all

[7] For a gravity approach to funding markets see Sander et al. (2016) and Qi et al. (2020) who document cultural differences as well as regulatory arbitrage as drivers of cross-border depositing, respectively. More generally, Bouvatier (2014) finds evidence for regulatory drivers of the cross-border supply of financial services.

[8] This is the seminal definition by Dornbusch (1980: p. 176). For an application in the European context see Lemmen (1998).

[9] For an early analysis of the relation between the interest rate pass-through and banking market integration see Sander and Kleimeier (2004).

[10] In our approach, there is only one case where theoretically the long-term equilibrium as defined in Eq. (1) would not be disturbed and would thus not incentivize the arbitrage processes that we investigate to test for deep integration. This is an ideal world of identical pass-through coefficients for all countries and fully integrated markets. In this very special case, our approach would find no evidence for arbitrage and we would diagnose no integration. Unlike quantity-based indicators, our approach would however not signal less integration when interest rate dispersion is reduced. In practice, we are always able to test for arbitrage because our estimates show that deviations from the long-run equilibrium are the rule. This is in line with Bernhofer and van Treeck (2013) who document substantial heterogeneity in the pass-through across Eurozone countries. For an analysis of the role of macroeconomic factors as drivers of the pass-through and its heterogeneity across countries see Sander and Kleimeier (2004) and Gregor and Melecký (2018).

[11] Based on a Cournot model of bank pricing, Corvoisier and Gropp (2002) show that European loans and demand deposits competition matters and that contestability in these markets had increased in Europe with deregulation in the 1990s. Sander and Kleimeier (2004) apply a 'cost-of-funds' approach to analyze the interest rate pass-through by using specific funding costs for each type of loans based on matched maturities.

banking markets.

Before the GFC, deposits rates in the Eurozone were generally in line with money market rates. In some cases, they were occasionally slightly higher, reflecting a relatively high demand for deposit funding that could and should not be matched by short-term borrowing in money markets or refinancing operations with the ECB. With the arrival of the GFC and Eurozone crisis, the ECB drastically reduced its refinancing rates (with the exemption of the 2011 interest rate hike) towards zero. More importantly, in addition to other unconventional measures such as "Forward Guidance" and the "Asset Purchase Programme", the ECB introduced Targeted Long-Term Refinancing Operations (TLTROs) on June 5, 2014, which provide financing to credit institutions up to 4 years.[12] As a consequence, money market rates have been decreasing and have dropped below the average deposit rate. To a varying degree, this is true for all Eurozone countries. Hence, EONIA rates are much closer to the real funding costs than deposit rates and the mark-up on the EONIA rate is a much better proxy for bank profitability, especially after the GFC. Thus, we prefer this margin for detecting cross-border arbitrage processes. Note that since the EONIA money market rate is the same throughout the Eurozone, Eq. (2) can also be written as,

$$L_t = e + fL_t^* + (1-f)\,F_t \tag{2}$$

Eq. (2') reveals that if margins are fully integrated ($f = 1$), then lending rates will also be fully integrated. However, as long as foreign and domestic loans are heterogenous, loan rates differ by the coefficient e. Integration of EONIA margins is thus a sufficient condition for lending rate integration but not for full convergence. It is, however, not a necessary condition as integration can also be brought about by arbitrage via cross-border lending and borrowing.

We therefore also investigate integration in terms of lending margins over EONIA as a complementary exercise to our analysis of lending rate integration and expect the EONIA margin results to confirm our lending rate results in particular after the GFC.

4. Methodology

Our objective is to analyze the development of shallow and deep banking market networks before, during and after the Eurozone crisis. Our preferred approach to measure deep banking market integration employs a causality methodology to detect and distinguish short- and long-term cross-border arbitrage in retail banking. In a first step, we estimate the full set of bilateral relationships between every single Eurozone member country and each of the other Eurozone member countries. However, investigating the relationships (1) and (2) by means of cointegration testing is just a first step in investigating the described arbitrage mechanisms. Bilateral relationships between rates or margins are not necessarily symmetric in the sense that arbitrage may be driven by cross-border activity emanating from one country only. Hence, in order to inform our network analysis sufficiently, we also need to investigate the direction of the arbitrage process. This can be done in a Granger causality model which allows us to establish whether one country's lending rate (margin) predicts the other country's lending rate (margin). Our definitive empirical model therefore needs to combine causality with cointegration. Estimating a Granger causality model which is extended by the error correction term (ECT) derived from the cointegration relationship allows us to simultaneously estimate and discriminate between (shallow) short-term dynamics and (deep) long-term adjustments to disequilibria via arbitrage processes. This information is then used in our network analysis to document the structure of deep and shallow networks and how the Eurozone crisis has affected these network structure. We concentrate on loans to non-financial corporations as these markets have regularly been shown as the most integrated and competitive ones in the Eurozone before the Euro crisis. Hence, we might be more predisposed to find integration than not, which is important when judging on disintegration processes resulting from the Euro crises.

4.1. Causality analysis

Granger causality establishes whether one time series contains useful information to predict another time series. If X can be predicted based on not just its own past values but also based on past values of Y, then X and Y are 'temporally related' (Granger and Newbold, 1977) and Y is said to Granger-cause X. We therefore estimate a bivariate vector autoregressive (VAR) model where X and Y represent the loan rate (or margin) time series for two EMU member countries to identify whether one country is influencing banking market conditions in another country.

$$X_t = \alpha + \sum_{i=1}^{k} \beta_i X_{t-i} + \sum_{i=1}^{k} \gamma_i Y_{t-i} + \varepsilon_t \tag{3}$$

$$\Delta X_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta X_{t-i} + \sum_{i=1}^{k} \gamma_i \Delta Y_{t-i} + \varepsilon_t \tag{4}$$

Eq. (3) applies to loan rates or margins that are stationary – that is I(0). Eq. (4) is used for non-stationary rates or margins.[13] We estimate both equations with a lag length of k = 4. Y Granger-causes X when the null hypothesis that all γ_i are equal to zero can be rejected using a standard F-test.

Additionally, we have to take into account whether or not the two time series are cointegrated (MacDonald and Kearney, 1987). On the one hand, Demetriades and Hussein (1996) argue that 'test statistics derived from a level VAR framework are not valid unless the variables employed are either I(0) or I(1) and cointegrated'. This implies that Eq. (3) could be used to model Granger causality for cointegrated time series. On the other hand, Engle and Granger (1987) and Granger (1988) argue that in the presence of cointegration, Granger causality models should be extended by the error correction term (ECT) derived from the cointegration relationship. We follow Engle and Granger (1987) and Granger (1988) and re-parameterize the Granger causality model in its equivalent error correction model (ECM) form only for I(1) and cointegrated time series:

$$\Delta X_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta X_{t-i} + \sum_{i=1}^{k} \gamma_i \Delta Y_{t-i} + \varphi ECT_{t-1} + \varepsilon_t \tag{5}$$

The ECT in Eq. (5) is the lagged, estimated error term of the bilateral cointegration model[14]:

$$X_t = \mu_0 + \mu_1 Y_t + \varepsilon_t \tag{6}$$

Eq. (5) allows us to differentiate between two different types of causality: Shallow integration is revealed by the short-run dynamics of the VAR. An F-test on the estimated coefficients γ_i provides evidence on short-term adjustment dynamics. Deep integration is revealed by a statistically significant cointegration relationship between any country-pair of lending rates and lending margins. Cointegration implies that although

[12] The 4-year maturity was introduced with TLTRO II in 2016. Another major feature of TLTRO is that borrowing rates become more favorable and closer to the (recently negative) rate on the ECB's deposit facility the more loans the banks provide to the real economy.

[13] There is also the possibility that one time series is found to be I(0) and the other I(1). In these cases, the I(1) time series will be included in the equation in terms of first differences whereas the I(0) time series will be included in levels. As the first differences of an I(1) time series will be I(0), this procedure ensures that all time series included in the equation are I(0). There is no evidence for I(2) among our lending rates and margins over EONIA.

[14] There is also the possibility of *nonlinear* cointegration and error adjustment. While this is beyond the scope of this paper, it offers a relevant and insightful avenue for future research.

two time-series can wander extensively they are still bound together by a stable long-term relationship. If one time series rises above this equilibrium level, then the ECT measures the speed of return to the long-term equilibrium level and is thus identifying the existence of an effective arbitrage process. Hence, a *t*-test on the estimated coefficient φ provides evidence on this arbitrage-type error correction mechanism.

Given these different Granger causality models, we proceed as follows: First, we test the time series for unit roots followed by tests for cointegration among all pairs of countries. Next to the standard Durbin-Watson (DW), Dickey-Fuller (DF) and Augmented Dickey Fuller (ADF) tests, we also apply Modified Dickey-Fuller (MDF) tests. Compared to DF and ADF tests, MDF tests rely on time series that have been transformed by a generalized least-squares regression (Elliott et al., 1996; Ng and Perron, 2001). If the time series are found to be I(0), causality testing according to Eq. (1) will be applied. If the time series are found to be I(1) and not cointegrated, causality testing according to Eq. (2) will be applied. If the time series are found to be I(1) and cointegrated, causality will be tested based on Eq. (3). The estimation is conducted separately for all three sub-periods. With the exception of a single time series, our unit root tests indicate that the time series included in our sample are not I(2).[15]

4.2. Network analysis

Having obtained our Granger causality results, we present and analyze them in a new and innovative network setting.[16] We consider two networks to characterize and visualize European banking market (dis)integration processes: the shallow network created by the short-run dynamics of the VAR, and the deep network created by the disequilibrium adjustment via arbitrage. Both shallow and deep networks can be disrupted by crises, yet restoring a deep network after a crisis requires restoring market interdependencies and not just reinstalling a uniform interest rate pass-through via unconventional monetary policy.

On the country level, we calculate the basic network measures of *in-degree* and *out-degree* for each country and both networks. In-degree is defined as the number of direct neighbors with which the focal country (called node in network terminology) has an inward connection. For our Granger causality networks, this translates into the number of other Eurozone countries which Granger-cause the loan rate (or margin) of the focal country. Similarly, out-degree is defined as the number of direct neighbors with which the focal country has an outward connection. For our Granger causality networks, this translates into the number of other Eurozone countries which are Granger-caused by the loan rate (or margin) of the focal country. We also present the inward and outward connections in graphical form. This allows us to visualize the exact countries which are connected bilaterally and the direction of the causality between the two countries.

On the network level, we calculate three network measures each for both networks: First, *density* measures the number of actual connections in % of total possible connections. Second, *reciprocity* measures the ratio of the number of connections pointing in both directions to the total number of existing connections. Reciprocity equals 1 in a purely bi-directional network and 0 in a purely uni-directional network. Third, we identify the *number of components* that the network has and which country belongs to which component. A component is a set of countries that are only connected among each other. The more integrated the Eurozone banking market, the higher its density and reciprocity and the lower the number of components.

5. Data and sample periods

We obtain interest rates for corporate loans in each of the original 11 EMU member states plus Greece from the ECB's MFI Interest Rate Statistics, i.e. Cost of Borrowing Indicators, available at https://sdw.ecb.europa.eu/browse.do?node=9691123. We select Total Cost of Borrowing to Non-Financial Corporations (series A2I). We calculate margins between loan rates and the money market rate, e.g., EONIA, also from the ECB. These series have the advantage that they are harmonized across countries, are available for all 11 original EMU member countries plus Greece and that they reflect interest rates or margins for new loans signed in a given month. For robustness checks, we consider margins between loan rates and the deposit rate. We obtain these margins from the ECB's MFI Interest Rate Statistics, i.e. Bank Lending Margins, and select Lending Margins on Loans to Non-Financial Corporations (series LMGLNFC). The ECB measures lending margins as 'the difference between MFIs' interest rates on new business loans and a weighted average interest rate on new deposits from households and non-financial corporations. … interest rates refer to loans to euro area residents'. All series are available on a monthly basis from January 2003 to June 2019.[17]

Fig. 1 shows the development of loan rates and margins aggregated to the EMU level.[18] The cross-country means in Panel A reveal that despite the decline of the lending rates, lending margins stay rather stable also during and after the Euro crisis. Panel B shows the increase in cross-country dispersion until Draghi's 'whatever-it-takes' speech and its decline thereafter. Remarkably, the dispersion of lending margins increases and remains at a high level. The latter possibly indicates that cross-border arbitrage processes have not fully been restored. The former convergence may therefore just be the result of realigning money market rates and a restored interest-rate pass-through process. These dynamics are exactly what we intent to reveal with our methodology.

To show the impact of the Eurozone crisis, we differentiate three different sub-periods within our sample period of January 2003 to June 2019. The selection of sub-periods is based on crucial events and developments in the Eurozone rather than on global events. In particular,

[15] Table A4 in the Online Appendix reveals that the MDF(1) test is only significant at the 10% level and the MDF(opt) test is insignificant for French corporate loan margins over deposit rates during the post crisis period. When testing the second difference of the French corporate loan margins over deposit rates, we find MDF(1) = 4.91*** and MDF(opt) = −1.30 with an optimal lag length of 4. Thus, this series is indeed I(2) during the post crisis period. In our paper, we focus on corporate loan rates and corporate loan margins over money market rates and consider corporate loan margins over deposit rates only as a robustness check. As only one of the 12 interest margin series is I(2), we do not believe this to be a substantial problem.

[16] Network analysis is increasingly being used to investigate a diverse set of financial and economic issues (see e.g., Acemoglu et al., 2012; Contreras et al., 2019; Borochin and Rush, 2022) including financial integration (see e.g., Schiavo et al., 2010; Bhattacharya et al., 2018).

[17] Following Regulation ECB/2001/18, the harmonized MFI Interest Rate Statistics (MIR) replaced the non-harmonized Retail Interest Rates (RIR). RIR typically end in June 2003 and are incompatible with MIR so that interest rate series cannot be merged. At the time of the introduction of the MIR, some researchers considered to connect both databases but ultimately decided against it due to the break in the interest rate series introduced by the switch from RIR to MIR - see for example Baugnet and Hradisky (2004) and von Borstel (2008). The exception are Sørensen and Werner (2006) but they are at best able to replicate some of the time series dynamics of the RIR series (see their Chart A3.B). For our analyses, we prefer the MIR statistics due to their harmonization. The non-harmonized RIR reflect series based on different national definitions and classifications which leads to biases that hinder cross-country comparisons (Sørensen and Werner, 2006). von Borstel (2008) for example reports that the non-harmonized RIR have led to a downward bias in pass-through estimates for Germany compared to other countries. Baugnet and Hradisky (2004, p. 56) express the superiority of MIR over RIR most clearly when they state that 'the harmonized statistics of the MIR survey offer the first opportunity to make a valid comparison between Belgium and the euro area'.

[18] In addition, Tables A1 to A3 in the Online Appendix provide detailed descriptive statistics for our time series on a national level. Figure A1 in the Online Appendix graphically presents the development of our series over time. The correlations presented in Table A3 are in line with our dispersion argumentation based on Fig. 1.

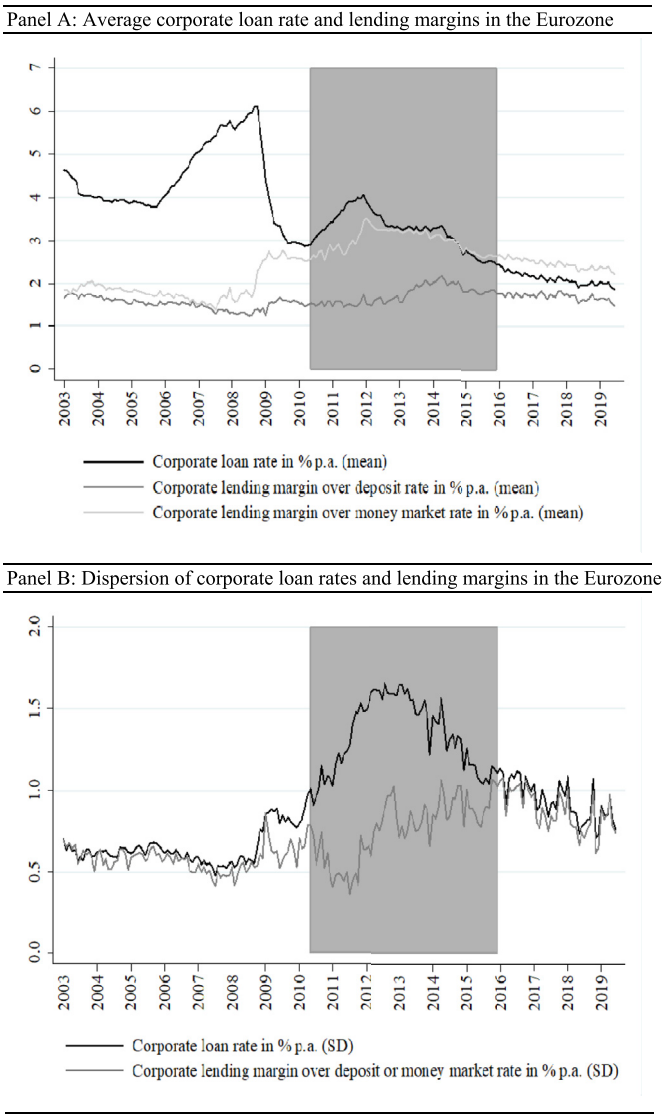

Fig. 1. Development of Corporate Loan Rates and Margins in the Eurozone. *Notes*: This figure plots the cross-country average and standard deviation (SD) of corporate loan rates and margins on a monthly frequency from January 2003 to June 2019. The grey area identifies the crisis subperiod. Source: Authors' depiction based on ECB's interest rate data.

we start the crisis period only in May 2010 when Greece concluded the first three-year financial assistant program with the Eurozone countries and the IMF. In February 2010, the Greek government revealed that budget data had previously been misreported which led to a sharp rise of Greek government borrowing cost in March. This triggered what is now known as the "doom loop", a previously unseen interdependence of deteriorating government finances and worsening bank balance sheets. Hence, we define a stable period from January 2003 to January 2010, rather than using the GFC as the starting point for the crisis period. To be cautious we start the crisis period only in May 2010. The endpoint is equally crucial. Except for Greece, all countries had exited the ESM/EFSF assistance programs by 2015, with Portugal being the last to do so in May 2014. As Greece failed to repay an IMF loan in June 2015, a new ESM program was approved in August 2015 and successfully concluded by August 2018 without major issues occurring until then.[19] Hence, we opt to end the crisis period conservatively on December 2015 and define a post-crisis period from January 2016 to June 2019. Our crisis period is indicated by the shaded areas in Fig. 1, which is indeed a distinct period in terms of interest rate and margin development already by simple "eye inspection". This strategy is corroborated by using the GFC as an alternative, but less meaningful crisis starting point in the context of our analysis.

6. Results

We present our results in a set of Tables and Figures. Table 1 presents the results of our Granger causality analysis on the country level while Figs. 2 and 3 present network graphs which plot the bilateral causality relationships and indicate the direction of the causality. For each country-pair, we estimate the shallow short-run causality dynamics (VAR) and the deep long-term disequilibrium adjustment (ECM) between their corporate loan rates and lending margins before, during and after the Euro crisis. Table 2 condenses the detailed information presented in Table 1 by presenting aggregate network measures.[20] Detailed results regarding unit root testing, cointegration testing, and Granger causality modelling are shown in Tables A1 to A10 in the Online Appendix.

6.1. Banking market networks for corporate loan rates

For corporate loan rates, Fig. 2 shows how national interest rates are both influenced by and influence other countries' rates. An arrow pointing from country A to B indicates that country A Granger-causes country B. The entirety of all arrows constitutes the network. Fig. 2 clearly reveals how the short-run causality dynamics and long-term disequilibrium adjustments change over time. During the stable period, the corporate loan rates of all Eurozone countries are connected via short-run causality. The network thus consists of a single component, indicating that all 12 countries are connected in a single network. Consider for example the focal country of Belgium. In terms of short-term VAR linkages, its corporate loan rate is Granger-caused by eight of the other 11 EMU loan rates while the Belgian corporate loan rate Granger-causes rates in ten of the other 11 EMU countries. Panel A of Table 1 shows that this pattern is typical for the stable period with each focal country either showing that interest rates are being influenced by at least eight other countries (in-degree) or influencing at least eight other countries (out-degree). In the case of Belgium, Finland, Luxembourg and the Netherlands, both in- and out-degree are above seven, indicating that corporate loan rates in these countries both Granger-cause and are Granger-caused by rates in a large number of other Eurozone countries. During this stable period, Germany and France (as well as Spain, where lending to the real estate sector was very attractive for foreign banks) Granger-cause lending rates in 11 and ten Eurozone countries, respectively, while in-degree linkages are standing at four only.

The aggregate network measures in Table 2 also support this impression of a single, strongly connected and often bi-directionally network of short-term VAR dynamics for corporate loan rates during the stable period. For network density, defined as the number of actual connections in per cent of total possible connections, we find a value of 0.68 indicating that on average, each country is connected to 68 per cent

[19] The program with Greece was positively reviewed in 2016 and additional debt relief measures were taken in 2016 and 2017. All data are from the European Stability Mechanism's website at www.esm.europa.eu.

[20] These Tables and Figures assume that a bilateral causality relationship exists when it is statistically significant at the 5% level. Tables A13 to A16 and Figures A2 to A5 in the Online Appendix present results for 1% and 10% significance levels, respectively. The overall interpretation of our results is robust to these alternative significance levels. The Online Appendix also includes the results for corporate loan margins over deposit rates. While both margin types show somewhat individual patterns, the general result of a disintegrating Eurozone banking network, i.e., for long-term arbitrage processes after the crisis, is robust.

Table 1
Country characteristics in the granger causality networks for corporate loan rates and margins.

Country	Network of VAR effects									Network of ECM effects								
	Stable period			Crisis period			Post crisis period			Stable period			Crisis period			Post crisis period		
	In-degree	Out-degree	Compo-nent	In-degree	Out-degree	Compo-nent	In-degree	Out-degree	Compo-nent	In-degree	Out-degree	Compo-nent	In-degree	Out-degree	Compo-nent	In-degree	Out-degree	Compo-nent
Panel A: Corporate loan rates																		
Austria	11	3	1	2	6	1	2	0	1	1	7	1	2	7	1	0	0	2
Belgium	8	10	1	0	7	1	2	5	1	4	6	1	8	5	1	0	0	3
Finland	7	9	1	2	2	1	2	0	1	9	1	1	11	5	1	0	0	4
France	4	10	1	2	2	1	0	3	1	5	8	1	0	9	1	0	0	5
Germany	4	11	1	1	4	1	2	4	1	7	4	1	3	7	1	0	0	6
Greece	9	3	1	4	0	1	4	0	1	6	6	1	11	6	1	0	0	7
Ireland	9	6	1	6	0	1	0	0	2	8	3	1	11	4	1	0	0	8
Italy	6	8	1	2	3	1	2	4	1	0	9	1	0	5	1	2	3	1
Luxembourg	8	10	1	1	1	1	1	2	1	10	0	1	4	3	1	3	0	1
Netherlands	9	7	1	2	2	1	1	2	1	8	5	1	9	6	1	0	0	9
Portugal	11	2	1	1	3	1	2	1	1	2	3	1	2	7	1	1	3	1
Spain	4	11	1	8	1	1	3	0	1	1	9	1	8	5	1	2	2	1
Panel B: Corporate loan margins over money market rates																		
Austria	1	4	1	0	1	1	2	0	1	7	4	1	0	0	2	0	0	2
Belgium	5	1	1	2	2	1	0	4	1	10	3	1	5	6	1	0	0	3
Finland	1	3	1	1	3	1	1	1	1	11	4	1	0	0	3	0	0	4
France	0	4	1	2	1	1	2	2	1	6	8	1	6	3	1	0	0	5
Germany	1	1	1	3	3	1	2	2	1	2	10	1	0	0	4	0	0	6
Greece	1	3	1	2	1	1	3	0	1	0	11	1	7	5	1	0	0	7
Ireland	2	2	1	5	0	1	0	0	2	11	3	1	7	5	1	0	0	8
Italy	1	4	1	4	6	1	2	4	1	4	8	1	1	7	1	2	3	1
Luxembourg	11	0	1	1	1	1	1	2	1	11	9	1	0	0	5	3	0	1
Netherlands	3	2	1	2	5	1	1	1	1	8	9	1	7	2	1	0	0	9
Portugal	4	4	1	1	3	1	1	1	1	5	8	1	5	5	1	1	3	1
Spain	0	2	1	4	1	1	2	0	1	7	5	1	2	7	1	2	2	1

Notes: This table shows the details for the networks defined by the bilateral Granger causality relationships among the eurozone countries. The out-degree represents the number of outgoing Granger causality relationships. The in-degree represents the number of incoming Granger causality relationships. Countries that belong to the same component are assigned the same component number. Countries that are not connected to any other country during the respective subperiod have an in-degree of zero and an out-degree of zero and thus form their own component. Granger causality is assessed at the 5% significance level based on Tables A8 to A9 in the Online Appendix. Source: Authors' calculations based on ECB's interest rate data.

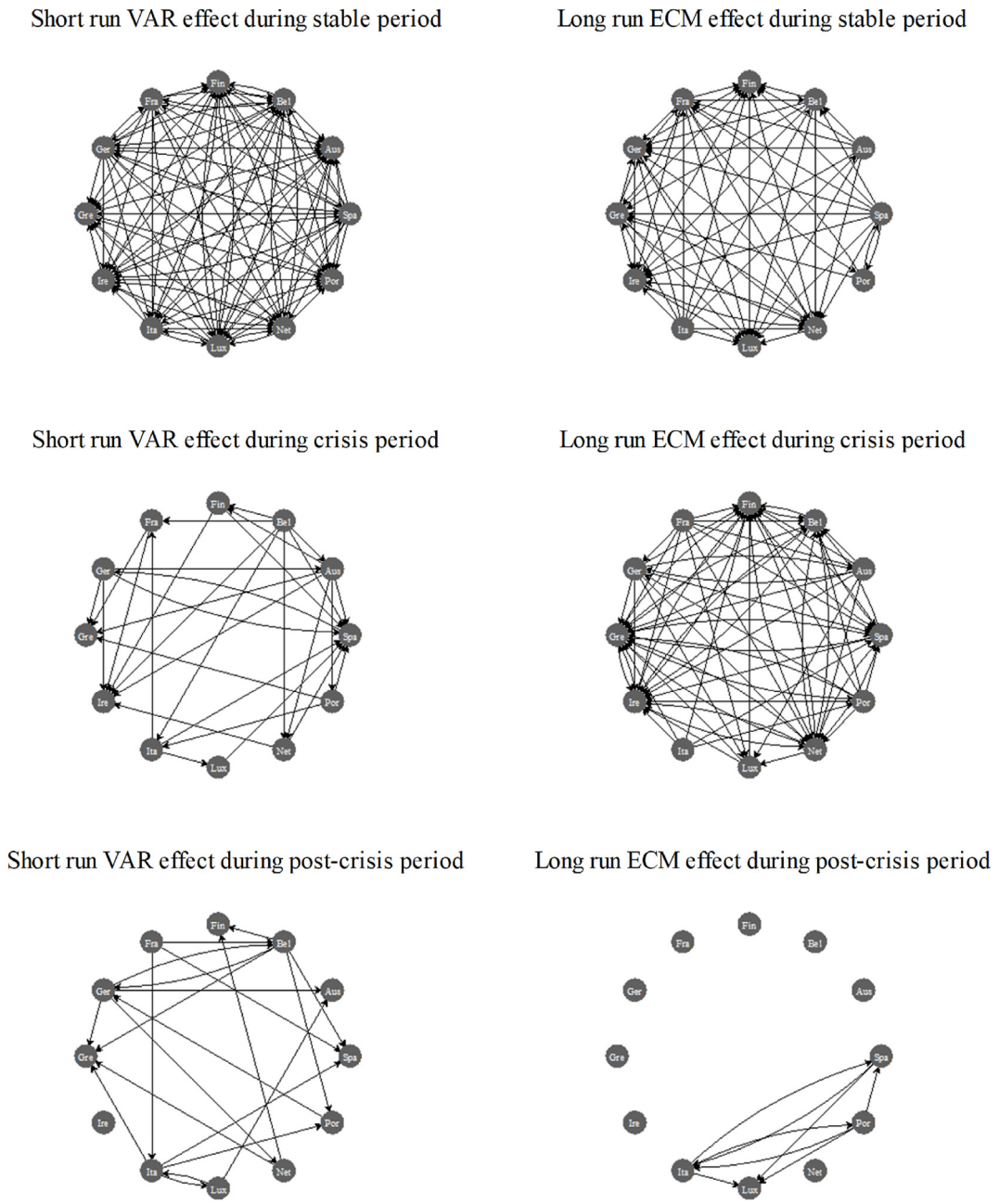

Fig. 2. Granger Causality Networks for Corporate Loan Rates. *Notes*: This figure show the networks defined by the bilateral Granger causality relationships among the Eurozone countries. An arrow pointing from country A to B indicates that country A Granger-causes country B. For the short run VAR network, Granger causality exists, e.g. an arrow is shown, when the F-test is significant at least at the 5% level. For the long run ECT network, Granger causality exists, e.g. an arrow is shown, when cointegration is found to exist and when the ECT coefficient is significant at least at the 5% level. See Online Appendix Table A8. Source: Authors' calculations based on ECB's interest rate data.

of the remaining 11 Eurozone countries. Furthermore, reciprocity, which measures the ratio of the number of links pointing in both directions to the total number of existing links, equals 0.36 indicating that 36 per cent of existing causal linkages are bi-directional.

The GFC and following Euro crisis have however substantially altered this network of short-term VAR dynamics.[21] Fig. 2 shows a much less connected network during the crisis period. This suggests that the crisis weakens the level of Eurozone integration. The network measures in Table 2 support this interpretation. Density and reciprocity fall dramatically during the crisis period before recovering slightly, though not fully, during the post-crisis period. However, Table 1 shows that we still have only one component during the crisis period, suggesting that all countries remain part of a single network in terms of short-term VAR dynamics. The number of components increases to two during the post-crisis period as Ireland's corporate loan rates are now outside the single network.

Looking at the long-term disequilibrium adjustments that connect the corporate loan rates, we see a different development of deep integration

[21] We do not analyze the GFC period specifically. However, its hot phase which lasted from 2007 to 2009 (Claessens et al., 2010) is still part of our stable period prior to the Eurozone crisis. In fact, quantity-based evidence suggests that the GFC had a strong effect on cross-border banking in wholesale markets but a much weaker effect on cross-border banking in Eurozone retail markets, which appeared more resilient to the GFC than inter-bank markets (Sander and Kleimeier, 2013; Luna and Van Rixtel, 2014).

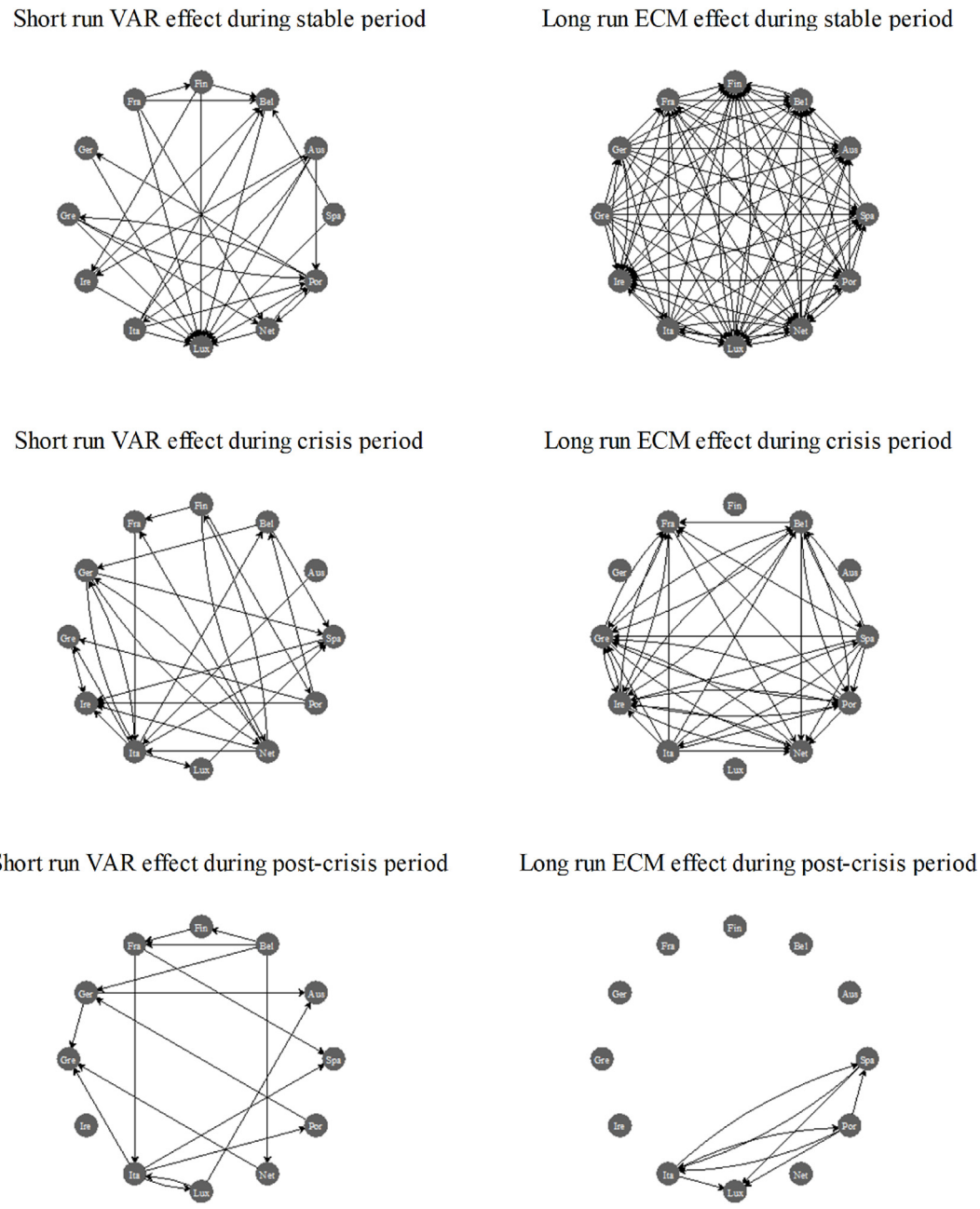

Fig. 3. Granger Causality Networks for Corporate Loan Margins Over Money Market Rates. *Notes*: This figure show the networks defined by the bilateral Granger causality relationships among the Eurozone countries. An arrow pointing from country A to B indicates that country A Granger-causes country B. For the short run VAR network, Granger causality exists, e.g. an arrow is shown, when the F-test is significant at least at the 5% level. For the long run ECT network, Granger causality exists, e.g. an arrow is shown, when cointegration is found to exist and when the ECT coefficient is significant at least at the 5% level. See Online Appendix Table A9. Source: Authors' calculations based on ECB's interest rate data.

over time. During the stable period, these long-term adjustments are slightly less pronounced than the short-term dynamics as Fig. 2 and the network measures in Tables 1 and 2 show. However, the crisis strengthens rather than weakens these long-term disequilibrium adjustments, as evidenced by the network's increasing density and reciprocity (Table 2). Yet, the devil is in the detail as the bilateral causal relationships change considerably during the crisis. For example, German and French loan rates are less Granger-caused by other countries' rates but more often Granger-cause rates elsewhere, while rates in Greece and Ireland are influenced by the rates of all other countries (Table 1).

Greece and Ireland are particularly interesting cases because the number of short-run VAR effects on these two countries decreases during the crisis period, while all other countries have an impact on these two countries in restoring the equilibrium relationship. However, the nature of the equilibrium relationships changes from the pre-crisis to the crisis period. Not surprisingly, idiosyncratic risk increases during the crisis period for these (and other) crisis-affected countries as reflected by a higher value of coefficient a in Eq. (1), thus widening the equilibrium difference between loan rates (see Table A5 in the Online Appendix). These larger equilibrium differences reflect these countries' (perceived) higher credit risks. Greek banks, for example, raised lending rates as non-performing loans increased and sovereign credit risk spilled over into the corporate loan market (Louzis et al., 2012; Drago and Gallo, 2017; Tables A1 and A2 in the Online Appendix). The larger equilibrium differences can also reflect other distortions, such as speculations on Greece's EMU exit. Larger equilibrium differences do, however, not

Table 2
Network characteristics in the Granger causality networks.

Period	Network of VAR effects			Network of ECM effects		
	Density	Reciprocity	Number of components	Density	Reciprocity	Number of components
Panel A: Corporate loan rates						
Stable period	0.68	0.36	1	0.46	0.11	1
Crisis period	0.23	0.03	1	0.52	0.30	1
Post-crisis period	0.16	0.11	2	0.06	0.33	9
Panel B: Corporate loan margins over money market rates						
Stable period	0.23	0.11	1	0.62	0.28	1
Crisis period	0.20	0.13	1	0.30	0.43	5
Post-crisis period	0.13	0.06	2	0.06	0.33	9

Notes: This table shows the characteristics of the networks defined by the bilateral Granger causality relationships among the Eurozone countries. Granger causality is assessed at the 5% significance level based on Tables A8 and A9 in the Online Appendix. Source: Authors' calculations based on ECB's interest rate data.

necessarily go hand in hand with a disruption of arbitrage processes. In fact, arbitrage can intensify to adjust to the new realities. For example, banks can reduce or increase their cross-border lending, thereby influencing loan rates in the affected countries. In the case of our two countries, it is striking that the average coefficient *b* vis-a-vis all partner countries increases for Greece but decreases for Ireland. Hence, there is no uniform reaction and every country-pair shows its own adjustment pattern to the crisis. While the various country-pair specific patterns can be studied in more depth, such detailed analyses are beyond the scope of our paper.

Most importantly, and in sharp contrast to the short-term dynamics, we find that during the post-crisis period the density of the network deteriorates and the number of components jumps to nine (Table 2). Only corporate loan rates in Italy, Portugal, Spain, and – somewhat surprisingly – Luxembourg, belong to the same component and show long-term disequilibrium adjustments (Table 1). In sum, while shallow integration shows some signs of revival, deep integration that survived better during the crisis period, is almost completely breaking down during the post-crisis period (Fig. 2).

6.2. Banking market networks for corporate loan margins

Compared to lending rates, corporate lending margins are better indicators of deeper (dis-) integration patterns. The network reveals to what extent higher margins in one country lead to arbitrage activities from the national banking markets in the network. In comparison to corporate loan rates, the short-run causality network is – as expected – weaker during the stable period. When deteriorating first during, and further after the crisis, the short-run causality networks becomes comparable to the lending rate networks during these periods as Fig. 3 and the network measures in Tables 1 and 2 indicate. In particular during the post-crisis period, both lending rate and margin networks display the same two components consisting of the same countries. Interestingly for margins over money market rates, we observe that Germany, Greece, Luxembourg, Spain and Portugal belong to the same component during the post-crisis period (Table 1). This group partly resembles the group that Bayoumi and Eichengreen (2020) identify as a core group reacting similarly to macroeconomic shocks. While their group comprises Germany, Greece, Ireland, Italy, Portugal and Spain in a sample ending in 2014, we concur with the authors' suggestion that also our results 'may reflect distortions in operation of the monetary union as much as underlying integration'.

During the stable and crisis periods there is more evidence for the existence of long-term disequilibrium adjustment than for short-run causality, thus leading to a network with a higher density and reciprocity. However, the number of components is higher for the network of long-term disequilibrium adjustment than for the network of short-run causality (Table 2). During the stable period, all countries are directly or indirectly related to each other so that the network consists of a single component. During the crisis period, Austria, Finland, Germany and Luxembourg are unrelated to any other Eurozone country while the remaining eight countries form one component. During the post-crisis period, the network falls apart and the same network as for loan rates emerges, e.g., only Italy. Luxembourg, Portugal and Spain are bi-directionally linked in the long-term (Table 1).

In sum, although unconventional monetary policies have helped to restore a more uniform interest-rate pass through across the Eurozone (see e.g., Bowman et al., 2015; Garcia-Posada and Marchetti, 2016; Benetton and Fantino, 2021), this has not been sufficient to restore deep banking market integration. We find that the Eurozone banking network disintegrates after the crisis and that this disintegration is particularly long-lasting. This is particularly evident in long-term arbitrage processes as opposed to short-run VAR dynamics, which occasionally show premature signs of revival. Moreover, our analysis documents that during the crisis some astonishing pairings and transitional relationships are established, which should be read as expressions of distortion rather than signs of partial integration.

7. Conclusions

Twenty years after launching the experiment of a single currency without establishing a single banking market, the vulnerability of this approach has become clear to monetary and financial integration experts as well as policymakers. In this paper, we propose a novel combination of state-of-the-art network analyses and estimates of Granger-causal bilateral interest rate and margin linkages for heterogeneous banking markets. Our proposed measure is superior to correlation metrics in identifying deep integration understood as a crisis-resilient arbitrage mechanism and can distinguish deep from shallow integration. Hence, our results indicate that increasing correlations of interest rates should not be misread as signs of integration. Instead, we document how a network of shallow banking market integration can rapidly disintegrate. However, our analysis, like all price-based analyses, has its limitations, too. In particular, it is not well suited to identify the underlying drivers of integration and dis-integration. Here, quantity-based analyses as well as detailed country studies are valuable complementary exercises for expanding our understanding of the emergence of deep integration. Yet, in order to draw correct policy conclusions, policy makers need to be aware of the respective strengths and weaknesses of these different integration measures. Our approach complements existing integration analyses based on price- quantity- and news-based measures, such as the ECB's financial integration reports. Because financial integration, particularly banking market integration, is an important pillar for risk-sharing in a monetary union that lacks a political union, our discovery of a deeply disrupted network lends support to calls to complete the European Banking Union in all of its aspects, particularly the currently still missing European Deposit Insurance. Completing the Banking Union and – as argued by Hoffmann et al. (2019) – the complementary Capital

Market Union could thus be the missing links that enable the common currency to unify the increasingly fragmented Eurozone banking markets, as envisioned by Tommaso Padoa-Schioppa more than 20 years ago.

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Data statement

The data used in this manuscript are provided by the ECB and freely available at https://sdw.ecb.europa.eu/browse.do?node=9691123.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2022.105940.

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