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Editorial

November 2015

This third issue of the Economic Studies includes three contributions on very relevant topics for those interested in understanding the recent evolution and the current perspectives for the Portuguese economy. We do not have a common thread, though all of the articles directly or indirectly deal with the consequences of the financial and sovereign debt crises that have plagued the world economies including the Portuguese since 2008. One of the themes being studied is aligned with topics addressed in the previous issue of the Journal, in a contribution by Crosignani, Faria-and-Castro and Fonseca reviewing the evolution of some of the fundamental characteristics of the Portuguese banking system during the financial crisis and the sovereign debt in particular the evolution of the main components of the balance sheets of the monetary financial institutions. In this issue, Sofia Saldanha and Carla Soares study the evolution of the Portuguese segment of the interbank money market during the crises, specifically from January 2005 to December 2013, and they evaluate the impact generated by the unconventional monetary policies implemented in recent years by the European Central Bank. The article quantifies the interbank unsecured loans under the TARGET payments system with the participation of Portuguese banks. The maturities studied include overnight weekly and monthly loans, being overnight operations the most voluminous. Over the period under analysis, the study identifies a drop in the number and volume of overnight loans, especially from 2010 on and an increase in the proportion of transactions taking place between Portuguese banks. These facts are consistent with the idea that the crises led to the fragmentation of the European interbank market and to difficulties in accessing external financing by Portuguese banks. However, funding sources have not dried up as much as one might think as there was a temporary increase in the average amount of borrowing operations with weekly maturity. In addition to effects on quantities the paper also studies the effects on prices. After 2008 there was an increase in the dispersion of interest rates and since 2011 Portuguese banks face interest rates above the European benchmark rates. The second part of the article studies the effects of monetary policy measures of the ECB in the interbank market with Portuguese participants. The authors rely on a regression analysis to show that the increase in liquidity (in part due to operations with Fixed Rate Full Allotment and also to the extension of accepted collateral) led to a compression of interest rates and a reduction in the amounts traded. This result is consistent with central bank interventions having the effect of reducing liquidity demand by interbank market participants. In short, the monetary policy measures of the ECB allowed Portuguese banks to meet their

liquidity needs with costs that turned out to be lower than those that would have occurred in their absence.

The essay by Nuno Silva, entitled "The euro area financial network and the need for a better integration" seeks to identify the origins of the weaknesses of the financial system that led to the sovereign debt crisis and to find reform paths that increase the resilience of such systems. The starting point adopted was the estimation for the countries of the Euro of matrices with bilateral positions between institutional sectors measuring financial instruments that constitute assets for a type of entities and liabilities for another entity. The analysis included seven institutional sectors: non-financial corporations, monetary financial institutions, other financial institutions, insurance corporations and pension funds, general government, households and the rest of the world. They considered seven types of instruments: currency and deposits, securities other than shares (short and long term), loans (short and long term), insurance technical reserves and other debits and credits. As expected, the results of this exercise showed that instead of obtaining a European network with high densities in the relationships between all institutional sectors of all countries we obtain instead a set of national relatively closed networks whose connection to the outside occurs mainly via banks and governments, two sectors already very interconnected themselves. This lack of international diversification helps to explain the permanence and relevance of sovereign risk in a monetary union with freedom of capital movements. According to Nuno Silva it is necessary to reform the financial system mitigating the over-exposure of banks to residents. The international expansion of banks could be a solution but it can create other problems at the outset particularly if the institutions created are "too big to fail". An alternative is to promote and develop the securitized debt market. With a good regulatory system the securitization of mortgages and collateralized loans to small and medium enterprises can substantially contribute to a better distribution of the risks of national financial systems, with positive consequences for the diversification of the banks portfolios and thus to their robustness.

The paper by Jorge M. Andraz and Paulo M. M. Rodrigues is entitled "A reappraisal of eurozone countries output differentials" and it deals with the long-term issue of knowing if you are experiencing a convergence among the per capita products of countries in the eurozone. Andraz and Rodrigues present a brief critical survey of the literature, both in terms of growth models and regarding the main empirical contributions studying the issue. In contrast to the more usual approach to define convergence as a negative statistical relationship between the initial value of output per capita of a country and its subsequent growth rates, Andraz and Rodrigues favor a definition of convergence based on the stochastic properties of per capita GDP time series. In this approach the existence of convergence between two series means that the data has two properties. The first is that there are

no statistically significant differences in the deterministic trend components of per capita GDP (in logs). The second is that the non deterministic part of this series of differences is stationary. The authors use GDP per capita series for 14 European countries and analyze the 91 possible pairs of series of differences. Andr  z and Rodrigues use a regression model that identifies the existence of different regimes in stationary differences, thus distinguishing four situations: a) stationary in differences throughout the series, b) not stationary in differences throughout the series, c) change from non-stationary to stationary and the opposite situation, d) wherein the series starts with the differences being stationary and changing to non-stationary. The situations a) and c) imply a possible GDP per capita convergence while the situations b) and d) correspond to the absence of convergence. The authors grouped the 14 countries into two sets, the first including countries from north and central Europe and the second in countries from the south of Europe, including Portugal. Despite the large number of pairs and the heterogeneity of the results, overall these seem to indicate the existence of a convergence in per capita GDP among the countries of northern and central Europe. As for the countries of southern Europe the convergence with the countries from north and central Europe that may have existed once appears to have been interrupted. If confirmed this is a worrisome but not totally unexpected development given the economic evolution observed in the aftermath of the financial and sovereign debt crises.

The Portuguese money market throughout the crisis

What was the impact of ECB liquidity provision?

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November 2015

Abstract

Money markets were severely impaired by the financial and sovereign debt crises. We investigate how the Portuguese part of the euro unsecured interbank money market was affected by the crises and how the ECB's unconventional policy measures, in particular the fixed rate full allotment procedure, impacted the market. We adapt a widely used method in the economic literature to identify unsecured interbank loans – with maturities ranging from overnight to one-month – settled in TARGET payment system, in which at least one of the counterparties is a Portuguese bank. We find that the Portuguese unsecured money market was hit especially by the sovereign debt crisis. There was a significant reduction in market activity, both in the number of operations and in market turnover. Alongside, price dispersion increased and rates agreed upon loans became on average more expensive than the reference rate for the respective maturity. We also find that domestic loans were more expensive than loans traded with a foreign bank. Finally, by analyzing the impact of monetary policy measures taken during the crises' periods, we find that the increased intermediation by the central bank contributed to a compression of spreads and a reduction in loan amounts. We observe that banks perceived as riskier began being penalized during the crisis. (JEL: E58, G21)

Introduction

In normal times, interbank money markets are among the most liquid in the financial system. Well functioning money markets allow the smooth transmission of liquidity throughout the banking system. Monetary policy responds to aggregate liquidity shocks, while idiosyncratic shocks are absorbed in money markets. The financial crisis that began in August 2007 in the US severely impacted these markets, leading to, what some call, a run on interbank markets. Banks increased significantly their precautionary

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demand for liquidity and, at the same time, the market was asking for a high counterparty risk premium. For this reason, there was also a substitution from unsecured to secured interbank loans¹ (ECB 2015). Later on, in the euro area, the negative feedback loop between sovereigns and banks associated to the sovereign debt crisis led to a fragmentation of the market. Even though market conditions have recently improved, a proper assessment of these markets and of the monetary policy effects is of great relevance. Thus, the purpose of this paper is to get a better understanding of the Portuguese part of the euro unsecured interbank money market and evaluate how ECB's monetary policy measures impacted this market. With that purpose, we use effective transactions data, which is not easily available given the over-the-counter nature of the market.

We begin by identifying overnight, one-week and one-month operations settled in TARGET/TARGET2, the large value payment system owned and operated by the Eurosystem. In such a manner, it is possible to describe and quantify the activity of the Portuguese unsecured money market in great detail. Since overnight operations represent the largest share of operations and volumes traded, we merged these transactions with bank's balance sheet, monetary policy operations and reserve compliance data. Hence, we are able to test the impact of the fixed rate full allotment (FRFA) policy and of the excess liquidity created in the market. We find that monetary policy measures were effective in reducing interest rates. They also contributed to a reduction in market activity as a consequence of the increased intermediation by the ECB. The results are in line with the hypothesis of market segmentation across the euro area from which Portuguese banks seem to be penalized in the course of the sovereign debt crisis. Moreover, there is also evidence supporting price discrimination in the overnight market favoring banks with a higher solvency ratio, especially during the crisis.

The article is organized as follows. We begin by introducing the relevant economic literature, followed by a brief review of the major crisis' events and the Eurosystem's policy response to it. Then, we explain the data and methodology used to withdraw effective money market transactions. The following section describes the Portuguese money market based on our dataset, with a special emphasis on the crisis' period. Afterwards, we present a simple analysis of the effects of the policy measures pursued by the Eurosystem aimed at normalizing market conditions. We finish with some concluding remarks.

1. Our analysis is focused only in the unsecured part of the money market, for data availability reasons. However, one should have in mind that the fall in market activity discussed in the article is also justified by this substitution effect.

Literature review

The main function of money markets is to provide an environment for the distribution of liquidity between banks in the system, *i.e.*, banks with short-term liquidity surplus lend to those with shortages, fulfilling their reserve requirements and insuring against idiosyncratic liquidity shocks. It is in these markets where monetary policy impulses begin, since the central bank provides primary liquidity to banks at the target rate, which serves as a benchmark for the secondary market. A number of theoretical studies justify central bank intervention. When markets are efficient the central bank provides liquidity through open market operations, allowing institutions to endogenously reallocate it (Goodfriend and King 1988). However, in the presence of some inefficiency or market frictions, a more active central bank intervention is justified. It has been shown that during banking crises the central bank can use open market operations to provide liquidity and smooth interest rates (Goodfriend and King 1988; Allen et al. 2009). Some authors argue that when there are inefficiencies related with market-power issues - as when banks with greater liquidity surplus have more power -, the central bank can improve efficiency in the market and avoid situations such as a fire sale (Acharya et al. 2012). To do so, the central bank must be able to provide liquidity at a cost affordable to the banks in need. Thus, it should either be prepared to sustain losses, or it should be better than other investors at monitoring the loans. The policy implications of this are that (i) there are gains in having in the same institution the roles of both supervisor and lender of last resort and (ii) the central bank should be ready to accept less liquid collateral or to pump a large amount of liquidity. In Freixas et al. (2011), when there are aggregate liquidity shocks, such as the increased demand for liquidity observed during the crisis, the central bank should inject liquid assets into the banking system. In this way, these and other studies provide grounds for central banks' interventions in the last years.

This article also follows the empirical work of other researchers that have studied the impact of monetary policy measures. Focusing on money market's benchmark interest rates, some studies found that these measures helped reduce interbank spreads and/or volatility (Soares and Rodrigues 2013; Carpenter et al. 2014; Szccerbowicz 2014; Hesse and Frank 2009). However, only some studies use effective data on transactions. Brunetti et al. (2011) use e-MID² data and conclude that central bank intervention consistently adds uncertainty to the interbank market and that actions that do not target interbank asymmetric information fail to improve market liquidity. More recently, several papers using TARGET payments data study the crisis and the policy effects. Bräuning and Fecht (2012) use German data up to the end of

2. E-MID is an Italian interbank market electronic platform.

2008 and find evidence strongly supporting a liquidity effect and a reduction in market activity due to the increased central bank intermediation. Arciero et al. (2014) use data for the euro area, covering all maturities of the market and describing the euro market during the crisis. de Andoain et al. (2014) document the fragmentation in the euro overnight unsecured money market and conclude that policy measures were successful in reducing tensions, but did not eliminate them. Finally, Abbassi et al. (2015) focus only on two episodes, the Lehman default and the sovereign (Greek) debt crisis. They analyze both intensive and extensive margins of interbank lending – both on loan volumes and spreads – and study price dispersion based on a revealed preference argument – if during the same morning the same borrower is paying substantially different prices from different lenders, it implies that the borrower has limits to additional borrowing from the lender charging the lowest price. They find that price dispersion increased with both crises episodes, but that policy measures were effective in reducing it. Following these studies, this article contributes with an adaptation of the procedure for selecting operations of the recent Portuguese market and the evaluation of policy effects, filling a gap by analyzing one of the economies mostly affected by the sovereign debt crisis.

Events and policy responses

During the summer of 2007, the uncertainty surrounding the US subprime credit market provoked a suspension of redemptions for three investments funds by BNP Paribas. This event triggered the first stage of the financial crisis in the euro area and it was the link with the burst of the bubble in the subprime market (see Brunnermeier (2008) for a description of the crisis and its causes). As a consequence, the euro interbank money market froze, inducing the ECB to intervene through the injection of liquidity in the banking system during the following months, and by conducting more operations for larger amounts and maturities. The collapse of Lehman Brothers in September 2008 deteriorated the situation, requiring further central bank intervention. Besides regular monetary policy operations, the ECB further increased liquidity provision through an increased number of refinancing operations, accepted a broader range of collateral for these operations and opted for a fixed rate full allotment (FRFA) procedure at the main refinancing rate – at first only for main refinancing operations and later it was extended to all refinancing operations. The FRFA consists in a tender procedure where banks bid an amount which the central bank satisfies completely at a fixed rate that has been previously set. Consequentially, liquidity supply in the Eurosystem became demand-driven, inducing a significant excess liquidity in the euro banking system. Here, excess liquidity is defined as liquidity provided above the strict aggregate liquidity needs of the banking system, such as the demand

for banknotes or for minimum reserve compliance. Hence, the term ‘excess liquidity’ does not take into account banks’ preferences for liquidity – for instance keeping liquidity for precautionary motives.

Aside from the liquidity policy, the ECB pursued a series of adjustments to the standing facilities’ interest rate corridor that, naturally, also had an impact on the money market. Following the bankruptcy of Lehman Brothers, this corridor – that used to be 200 b.p. – was lowered to 100 b.p.. Even though the corridor returned to the previous 200 b.p. level for a short period of time, in response to worsened market conditions and in order to avoid a negative deposit facility rate when cutting official interest rates, the ECB tightened the corridor once more from 150 b.p. in May 2009 to 75 b.p. in November 2013.

By the end 2009, conditions in Europe deteriorated as the euro market reacted to misgivings about Greece’s government accounts. The sovereign debt crisis reinforced the instability in the euro area with successive requests for financial assistance³ and the uncertainty around both governments and banks – the results on banks stress tests did not ease the fears about the negative feedback loop between sovereigns and the banking system –, and was responsible for creating contrasting credit conditions among European countries. In particular, Portugal, Spain, Greece, Ireland and Italy experienced increased sovereign risk premia and decreased cross-border flows, also leading to a fragmentation of the euro money market (de Andoain et al. 2014).

The ECB, alongside with the objectives of easing banks’ funding conditions and, ultimately, supporting bank lending to the economy, responded with a series of measures in order to support money market activity and the narrowing of spreads. On the liquidity policy side, it included two 3-year LTROs, an increase in the eligible collateral and a reduction in the minimum reserve ratio. These measures were reinforced by two Covered Bond Purchase Programs, given its relevance for the funding of euro area banks, and the Securities Market Program, with the purpose of correcting the deficient price formation process in the bond market that was impairing the transmission mechanism.

Finally, the deterioration of the sovereign debt crisis and the surge of a non-trivial redenomination risk of the euro motivated the ECB president to ensure, in the summer 2012, the ECB would “do whatever it takes to preserve the euro”, followed by the launch of the Outright Monetary Transactions (OMT) program – the possibility of unlimited purchases of government bond securities with maturities between one and three years, conditional on the member state being in an European Financial Stability Facility (EFSF) macroeconomic adjustment program or a precautionary program –, to address this market instability. The OMT have not been activated so far.

3. Financial assistance requests: Greece in May 2010, Ireland in November 2010 and Portugal in April 2011

More recently, the weak inflation dynamics – with a decreasing trend in inflation expectations and the persistence of a sizeable economic slack – led the ECB to provide further monetary stimulus. In mid-2014 and in January 2015, it implemented a program of purchases of public and private sectors securities (Asset Purchase Program), and a series of refinancing operations designed in a way to promote lending to the real economy (Targeted Long-Term Refinancing Operations).

Data

The money market consists mostly of over-the-counter (OTC) transactions. Lender and borrower usually agree upon a loan amount, a term and an interest rate and settle the transaction through a settlement system. In the euro area, the majority of money market operations are settled via TARGET/TARGET2⁴, the Real-Time Gross Settlement System (RTGS) owned and operated by the Eurosystem⁵. Several types of payments go through TARGET, ranging from monetary policy operations and interbank transactions to payments involving other financial institutions such as securities settlement systems. The system is accessible to a large number of participants.

In this paper we use all transactions settled on the Portuguese component of TARGET managed by Banco de Portugal. Data available from TARGET payments has, among other things, information on the amount transferred, the date and exact time of the transaction, and a Bank Identifier Code (BIC) for both participants. It is important to mention that there are no upper or lower limits on the value of payments. Therefore, from TARGET data we are able to observe a payment made from one institution to another, but it is not possible to assure it corresponds to a short-term interbank loan. We apply a method already used in the economic literature to identify these operations in order to overcome this issue (Furfine 2007; Armantier and Copeland 2012; Arciero et al. 2014).

4. TARGET stands for “Trans-European Automated Real-time Gross settlement Express Transfer”. TARGET2 is an improvement on TARGET (system previously at work). The transition from the latter to the former was implemented in phases beginning in 19 November 2007 and completely concluded in May 2008. From now on we will use TARGET and TARGET2 interchangeably.

5. There are other large-value payment systems in the euro area, but of much more reduced dimension. In 2011, TARGET2 had a market share of 61% in quantities and 91% in value (see Banco de Portugal (2015)).

Identification of unsecured interbank money market transactions

We have a wide period of data covering the financial crisis and more than two years prior to the crisis period. Data has daily frequency and covers the period from 1 January 2005 to 31 December 2013. We are interested in selecting overnight, one-week, and one-month maturity payments, *i.e.*, transactions that correspond to rounded values going from institution i to j at day t , and in the opposite direction at day $t+1$, $t+7$, or $t+30$ ⁶ in an equal amount plus a plausible interest.

The first step was to carefully choose and match all pairwise combinations ij - ji in business days t and $t+1$, $t+7$ and $t+30$. Basing our decision on the relevant literature, we kept only the combinations with a first payment of a rounded amount larger or equal to EUR 100 000 and multiple of 100 000 (Farinha 2007; Fernandes 2011).

The next phase was to determine the transactions' annualized implicit interest rate and which of those lay inside a plausibility area. Since we have no information on the interest rate agreed upon each transaction, we need to define an interval where interest rates on interbank loans will most probably lay. In doing so, we use data on EONIA, EURIBOR⁷, the deposit facility rate and the marginal lending facility rate⁸. We contemplated different plausibility intervals around these benchmark rates, depending on the operations' maturity. For overnight payments we considered an interval with a lower bound equal to the minimum between EONIA minus 100 b.p. and the deposit facility rate, and an upper bound equal to the maximum between EONIA plus 100 b.p. and the marginal lending facility rate. For one week and one-month maturity operations we have a corridor of 100 b.p. above and below the corresponding EURIBOR reference rate. After selecting repayments equal to the original loan plus a plausible interest, we excluded the pairs of transactions with zero or negative implicit interest rate.

Finally, we may have some problems associated with multiple matches or with the identification of operations. Multiple matches may take place within the same day or between days, especially when reference rates approach the zero lower bound and plausibility areas for different maturities overlap. The most relevant criteria used to overcome intraday multiple matches was to

6. To avoid excluding interbank loans that actually took place, we allowed the algorithm to capture operations that happened between $t+5$ and $t+9$ (one-week), and between $t+27$ and $t+33$ (one-month).

7. EONIA is the effective overnight reference rate for the euro. EURIBOR is the rate "at which Euro interbank term deposits are offered" by and between prime banks in the euro area. This rate is used as a reference for one week and one month operations.

8. The Eurosystem offers credit institutions the marginal lending facility in order to obtain overnight liquidity from the central bank, against the presentation of sufficient eligible assets, at the marginal lending facility rate. It also offers credit institutions the deposit facility so banks are able to make overnight deposits with the central bank, at the deposit facility rate.

choose the operation with the interest rate closest to EONIA/EURIBOR. For the case of multiple matches that involve different days, the most relevant criteria was to opt for shorter-term transactions. Turning to problems with the identification of interbank loans, it could be that the algorithm incorrectly identifies a pair of payments as a bank loan (Type 1 error or false positive), or it can fail to identify a bank loan (Type 2 error or false negative). The accuracy of the algorithm diminishes with the maturity of the transaction and as the reference rate approaches the zero lower bound.

This method to identify money market loans has been widely used for the euro area (Arciero et al. 2014; Bräuning and Fecht 2012; Heijmans et al. 2011; Farinha 2007) as well as for other countries (Furfine 2007; Demiralp et al. 2006; Armantier and Copeland 2012). Some authors have performed validation tests on the method for parts of the euro money market. Arciero et al. (2014) used the Italian e-MID platform and de Frutos et al. (2013) the Spanish e-MID platform. Both concluded that up to three-month maturities the algorithm is very reliable for identifying unsecured interbank loans⁹. In the following section some descriptive statistics on the Portuguese interbank money market are presented.

Given that the purpose of the study is also to analyze the effect of non-conventional monetary policy measures, TARGET data had to be complemented with data on banks' balance sheets and monetary policy instruments. For the former, we accessed monthly data from supervisory reports at Banco de Portugal, and for the latter we gathered data on Portuguese monetary policy counterparties use of ECB policy instruments – such as reserve requirements, monetary policy operations, standing facilities, and collateral use.

Statistics

Market activity in quantities

During the nine year period considered in this study, the number of transactions in the market has reduced significantly. From 2005 to 2013 there were on average 50 daily transactions, from which 83% were overnight, 10% were one-week operations, and 7% were one-month maturity loans. Of these 50 daily operations, on average 26% were held between Portuguese banks.¹⁰

9. Arciero et al. (2014) show that the share of non-identified transactions in the best performing algorithm setup is 0.92%. On the other hand, the reliability of the algorithm for the Fed funds market is found to be significantly smaller (Armantier and Copeland 2012).

10. In the Appendix we present further detailed information supporting the statements made in the text.

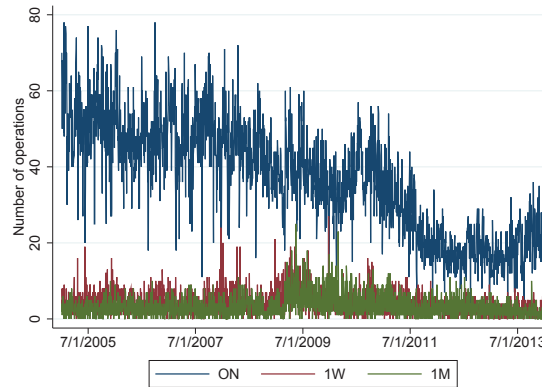


FIGURE 1: Number of operations per day

When we disaggregate operations by maturity we find that the decrease in market activity was due to the decrease in the overnight activity. From Figure 1 we can clearly see that along the whole period the daily number of interbank loans with one-week and one-month maturity contracts remained fairly constant. The number of overnight operations, on the other hand, progressively decreased, having had a major drop from 2010 onwards. We also find that in all three different maturity segments there was a considerable increase in the number of operations traded between domestic banks. From Figure 2, we can see that until the Lehman Brothers' collapse domestic operations were a small share of the market. In the particular case of overnight operations, loans between Portuguese banks represented less than 20% of all operations. After a period when almost no loans were being traded in the domestic market, the share of these operations began to increase, representing around 70% of the market by the end of the period. Thus, at a first glance we indeed find evidence of some market segmentation in the euro area, where Portuguese banks seem to face some difficulty in funding themselves outside.

Figure 3 gives a more detailed picture of the overnight cross-border market. The fall in the share of cross-border overnight operations coincided with a decrease in cross-border operations with a Portuguese lender, during the financial crisis. However, they still account for more than half of the transactions in the cross-border market. For one-week interbank loans the situation is slightly different. For the pre-crisis period, operations with a Portuguese lender account for most of cross-border activity. With the financial crisis the share of these transactions steadily dropped until 2012. Finally, when we look at the one-month maturity segment, it is visible that the share of operations with a Portuguese lender remained constant throughout the entire period, even though the share of cross-border operations as a whole has notably decreased with the financial crisis – at first these represented

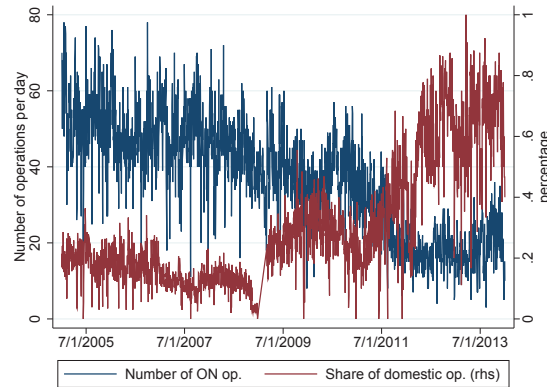


FIGURE 2: Overnight money market activity: share of operations in the domestic market

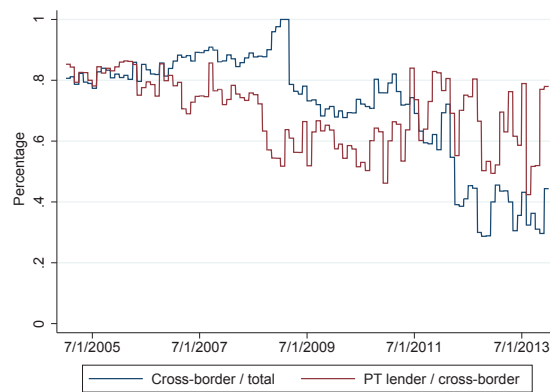


FIGURE 3: Cross-border market for overnight operations: share of activity according to counterparty origin

around 80% of the market and by the end of the period only around 40% (see Appendix B.1.).

Market turnover

The evolution of market turnover follows the evolution of the number of daily operations in the previous subsection. Figure 4 shows that the daily market turnover steadily decreased throughout the period. This reduction in market turnover was in great part a result of the decrease of the number of operations and of the average operation amount. In the particular case of the overnight market, which was the most impacted one, the average operation amount fell from 39 million euro before the crisis to 12 million between 2011 and 2013.

Notwithstanding, it is important to notice the high pick in turnover of one-week maturity operations between 2010 and 2012 which was due to a substantial increase in the average amount per transaction where a Portuguese bank receives a loan from a foreign counterpart (Figure 5). This suggests that Portuguese banks were still able to find funding outside, even though at a higher cost, as we shall see next. The period in which the increase took place corresponds to the beginning of the sovereign debt crisis in the euro area and it is the period when Portuguese banks were excluded from some international funding markets. Considering that credit risk is lower for shorter maturities, these developments indicate a substitution towards shorter maturities of the interbank money market funding.¹¹ However, our dataset does not allow us to prove this hypothesis. Arciero et al. (2014) also show an increase in cross-border loans in the peripheral countries of the euro area during the same period, alongside an increase in the rates agreed. Furthermore, another source of data, survey-based, points to the maintenance of the downward trend for the euro area as a whole (ECB 2015).

In the one-month maturity case the turnover, as the number of operations traded, remained fairly constant during the entire period in both the domestic and cross-border markets.

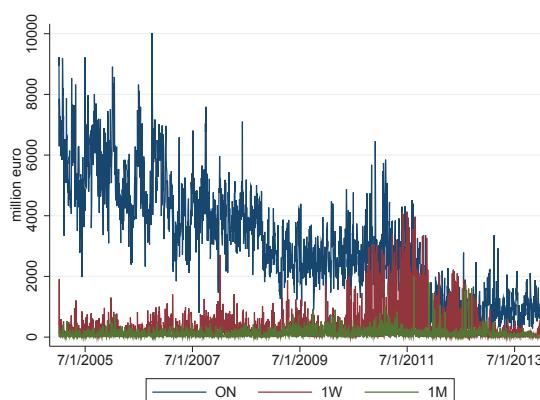


FIGURE 4: Daily turnover

11. Even though we only study overnight, one-week and one-month maturity operations, loans in the interbank money market usually have up to 1 year maturity.

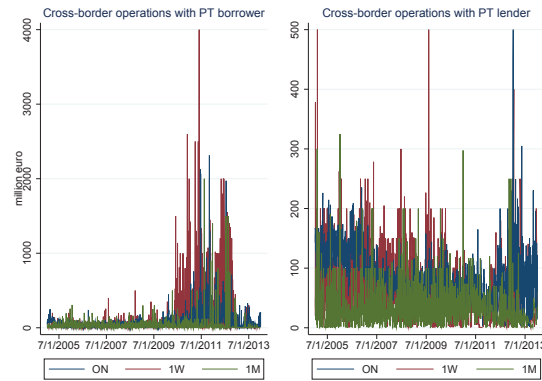


FIGURE 5: Daily average operation volume

Interest rates

In all the market segments, interest rates follow the respective benchmark interest rate closely – a consequence of the way the dataset is constructed, which identifies operations according to their proximity to the reference rate. The top panel of Figure 6 depicts the ECB’s standing facilities rates, EONIA and the daily overnight rates of the identified transactions. Even though in the first part of the sample interest rates do not show much variation around EONIA, beginning in the fourth quarter of 2008 the dispersion increases. When comparing the weighted average interest rate of the operations with EONIA it becomes clear that from 2011 onwards Portuguese banks are trading above the reference rate. Looking into more detail, during that period domestic operations are more expensive than cross-border ones. Finally, in the cross-border market there are also some differences in the way Portuguese lenders and borrowers were being priced. From 2010 to the middle of 2011 Portuguese borrowers were, on average, paying more than what Portuguese lenders were getting from foreign banks. From then onwards the situation is reversed and Portuguese borrowers were paying lower rates than the ones lenders were being able to get.

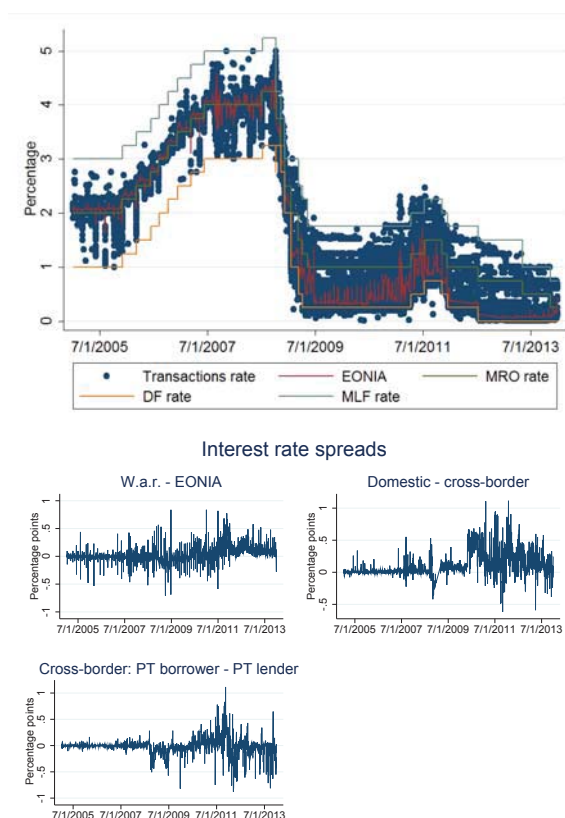


FIGURE 6: Overnight interest rates

In the one-week maturity case we will focus on the period when turnover in loans with this maturity increased. We find that around that time banks were trading slightly below EURIBOR, which may justify the increase in the average operation amount. Comparing rates from domestic and cross-border operations we find that domestic loans were priced below cross-border ones. Moreover, from the previous section we know the increase in turnover took place in cross-border operations with a Portuguese borrower, which are also priced above operations with a Portuguese lender, supporting the idea that there was some discrimination against Portuguese banks during the euro sovereign debt crisis (see Appendix B.2.).

The effects of monetary policy

Summing up, during the crisis we observed a fall in market activity and an increase in the dispersion of interest rates, while simultaneously several policy measures were being taken by the ECB. What is then the real effect

of these measures in the money market? With the purpose of understanding these effects we run a simple regression using our unsecured interbank money market transactions' dataset. In this section we focus on the overnight segment, because it is not only the one that concentrates the largest share of market activity, but it is also the most important maturity for the implementation of monetary policy.

The policy followed by the Eurosystem – especially the change to the FRFA procedure, and also the enlargement of the accepted collateral and the increase in the number and maturity of refinancing operations – resulted in the existence of an aggregate excess liquidity in the banking system (ECB 2014). Along these lines, we want to understand the effect of monetary policy measures as proxied by the Eurosystem's aggregate excess liquidity. The liquidity expansion and the measures decided by the Eurosystem were not designed to respond to specific developments in the Portuguese money market, but to euro area developments as a whole. Moreover, the equivalent excess liquidity in the Portuguese banking system was close to zero and it is uncorrelated to the Eurosystem's. For this reason, our policy variable (*EL* in Table 1) is exogenous, i.e., it influences the Portuguese money market but is not influenced by it.

The Portuguese money market activity was also influenced by the tensions in financial markets and the shifts in risk perceptions by market participants. In this way, we control for these effects by including two crisis variables in the analysis. The spread between the 1-month Euribor and the Overnight Interest rate Swap (OIS) is used as a proxy of the tensions in money markets in the euro area as a whole. The Portuguese sovereign debt Credit Default Swap (CDS) spread is a proxy for the sovereign debt crisis period.

The result of a transaction also depends on the two counterparties involved. From theory we would expect that larger banks would be able to find more favorable conditions in the market, or that two banks that trade more frequently would do it at better terms between them than with any other bank. Therefore, in our regression we control for the origin of the bank, *i.e.*, if it is either a domestic or a foreign bank. In the case of domestic banks we also control for banks' balance sheet characteristics. In order to account for the effect of the frequency of interactions between lenders and borrowers there are two variables that measure it, one for the lending side of the relationship and the other for the borrowing side. Moreover, there may be other banks' features that have an effect in the results. To account for those, we impose lender and borrower fixed effects in the regression. Finally, we try to take out the effects of some other factors that might influence the money market, such as changes in the standing facilities interest rates' corridor, or the days when refinancing operations were conducted.

Table 1 shows the results of the regressions for (1) the spread between the interest rate of the transaction and the ECB main policy rate and (2) the logarithm of the amount traded. Starting from our main policy variable

(*EL*), the Eurosystem liquidity expansion contributed to a compression of the spreads in the Portuguese market and to a fall in amounts traded, as the negative sign of the coefficient indicates. This result is consistent across all the different specifications that were tested. As the central bank increases intermediation in the market, the demand for liquidity by banks diminishes and, consequently, so does the price and quantity. We can say that the Eurosystem's policy measures were effective, at least to the extent that they allowed banks to continue to satisfy their liquidity needs and to do so at a lower cost than in their absence.

		(1) spread		(2) amount	
	EL	-0.0001	***	-0.0002	***
	1M euribor-ois	-0.0012	***	0.0001	
	PT sov cds	0.0002	***	-0.0001	***
borrower	solv ratio	-0.7293	***	-20.519	***
	assets	-0.0712	***	0.0724	
	liq ratio	0.0020	***	-0.0042	*
	ER	-0.0739	*	0.0494	
	foreign	-17.214	***	0.5961	
	frequent relation	-0.0009		0.0514	***
	solv ratio	-0.0609		-0.1190	
lender	assets	-0.1122	***	-0.0505	
	liq ratio	0.0019	***	0.0127	***
	ER	-0.0732	***	0.2128	***
	foreign	-21.014	***	-22.573	*
	frequent relation	0.0082	**	0.0900	***
	R2 overall	0.4943		0.5713	
	Nº obs.	52 601		52 601	

TABLE 1. Results of the regression for the spread and the log of the amount of the overnight transactions

Results for the estimation on the spread between the transaction interest rate and the ECB main policy rate or on the logarithm of the transaction amount. Data has daily frequency from January 2, 2005 up to December 31, 2013. The estimated model is a panel data model with fixed effects for the lender and the borrower, an AR(1) error term and robust standard errors. Variables definition: *EL* is the Eurosystem excess liquidity defined as the sum of excess reserves and net recourse to deposit facility; *1M euribor-ois* is the spread between the 1-month Euribor and the 1-month overnight interest swap; *PT sov cds* is the Portuguese sovereign debt Credit Default Swap spread; *solv ratio* is the bank solvency ratio; *assets* are the total assets of the bank in logarithms; *liq ratio* is the bank liquidity ratio; *ER* are the banks' excess reserves deposited at the central bank at the beginning of the day; *frequent relation* is the lender/borrower preference index defined as the share of the amount traded with the specific lender/borrower during a period of 30 days. Further control variables included in the estimation but not present in the table: dummy for intragroup operations, dummies for the periods when the standing facilities corridor diverged from 200 b.p. and dummies for Eurosystem refinancing operations. Banks' characteristics (solvency and liquidity ratios, assets and ER) are only available for domestic banks.

The effect of the two crises on Portuguese banks was distinct. The euro money market crisis had no significant impact on Portuguese banks activity

in the market. When we look at the effect on spreads, measured by the *1M euribor-ois* variable, we find that Portuguese banks even managed to trade at lower rates. On the other hand, the sovereign debt crisis significantly impacted Portuguese banks recourse to the money market. As the crisis heightened, Portuguese banks reduced the volume's traded and transactions became more expensive - the variable *PT sov cds* is significant in both regressions. This seems to be in line with the hypothesis of fragmentation of the market across jurisdictions.

Results on the banks' characteristics show that there is discrimination against banks perceived as riskier. When we run the same regression for separate periods, we conclude that the discrimination is only visible during the crisis. Before 2008, bank characteristics were not relevant for the pricing in the overnight market, which was a highly liquid market and with a very limited credit risk. However, the situation has changed since then. Banks with lower solvency ratios pay more for overnight loans, which are also made for larger amounts. As we can see from the results, banks' solvency ratio are only significant, in both regressions, when banks are borrowers (variable *solv ratio* in the table).

As one would expect, larger and foreign banks (variable *foreign*) usually trade at more favorable terms: transaction's rates are lower and amounts tend to be higher. Larger banks are those with a larger balance sheet as measured by the variable *assets* in both borrower and lender's characteristics. Finally, banks that trade more frequently do it for larger amounts (variable *frequent relation*).

Concluding remarks

Money markets are essential for monetary policy implementation and were among the most affected markets by the financial and sovereign crises. It is in the interest of policy to monitor conditions in these markets. However, it is difficult to obtain data on effective interbank market operations given that most of those are over-the-counter. Such problem became even more relevant to overcome as suspicions of the manipulation of interbank benchmark rates (EURIBOR, Libor) arose. In this paper we present a widely used method in the economic literature to identify unsecured interbank loans and we apply it to the Portuguese case. As a result, we are able to characterize the Portuguese unsecured interbank money market throughout the crisis. We reinforce the anecdotal evidence that there was a significant fall in market activity in the overnight segment, and we add evidence of a temporary increase in turnover in relatively longer maturities. Such events suggest that Portuguese banks recourse to the interbank market was not completely frozen. However, the price paid for loans to foreign banks was relatively high. Together with the significant fall in cross-border activity, this seems to favor the hypothesis

of the fragmentation of the euro area money market. The decreasing trend became more evident since 2010, suggesting that the contagion from the sovereign debt crisis also hit Portuguese banks via the recourse to the short-term interbank market. The results of the regression analysis support this idea. Indeed, Portuguese banks were negatively hit by the sovereign debt crisis, but not so much by the first stage of the financial crisis, even though it heavily hit money markets worldwide. Nonetheless, the Eurosystem's policy measures, which implied a significant liquidity expansion in the euro area, were effective in compressing the spreads of overnight operations, while implying a reduction in market activity. Finally, it is essential to mention that we find evidence in favor of a discrimination against banks perceived as riskier, in the overnight market, since the beginning of the crisis.

Appendix A: Summary table

		Overnight	1 week	1 month	Total
Number of operations	Jan 2005 - Aug 2007	51	6	4	58
	Sep 2007 - Dec 2010	41	8	7	50
	Jan 2011 - Dec 2013	23	4	4	29
Average daily volume (million of euros)	Jan 2005 - Aug 2007	5319,721	344,0919	135,7314	5638,512
	Sep 2007 - Dec 2010	3196,906	505,6533	181,5584	3627,952
	Jan 2011 - Dec 2013	1606,502	621,1228	180,7289	2138,818
Average daily volume per operation (million of euros)	Jan 2005 - Aug 2007	39,3096	16,34832	7,535697	34,83724
	Sep 2007 - Dec 2010	28,7322	30,15155	11,94909	27,63788
	Jan 2011 - Dec 2013	11,93885	27,59593	11,59309	13,37901
Average daily weighted interest rate	Jan 2005 - Aug 2007	2,768	2,834	2,929	2,772
	Sep 2007 - Dec 2010	2,108	1,796	1,707	2,024
	Jan 2011 - Dec 2013	0,561	0,698	0,624	0,588

TABLE A.1. Market activity summary

Appendix B: Additional figures

B.1. Market activity in quantities

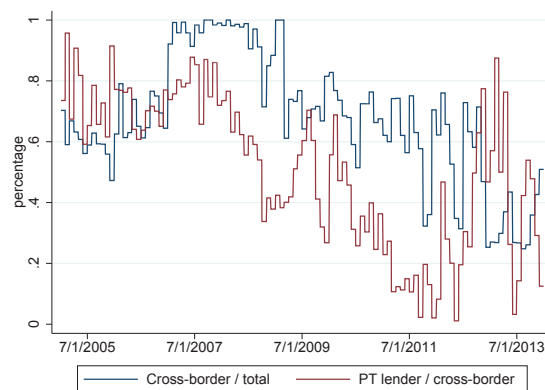


FIGURE B.1: Cross-border one-week market: share of activity according to counterparty origin

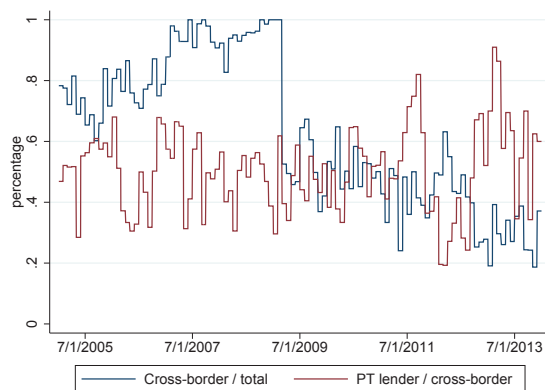
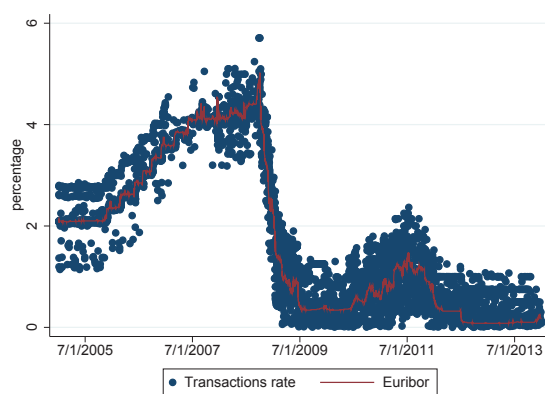


FIGURE B.2: Cross-border one-month market: share of activity according to counterparty origins

B.2. Interest rates



Interest rate spreads

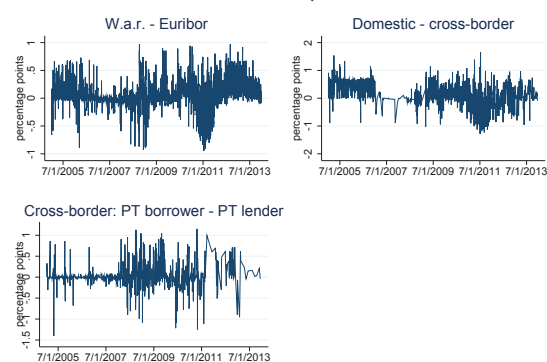


FIGURE B.3: Interest rates for one-week operations

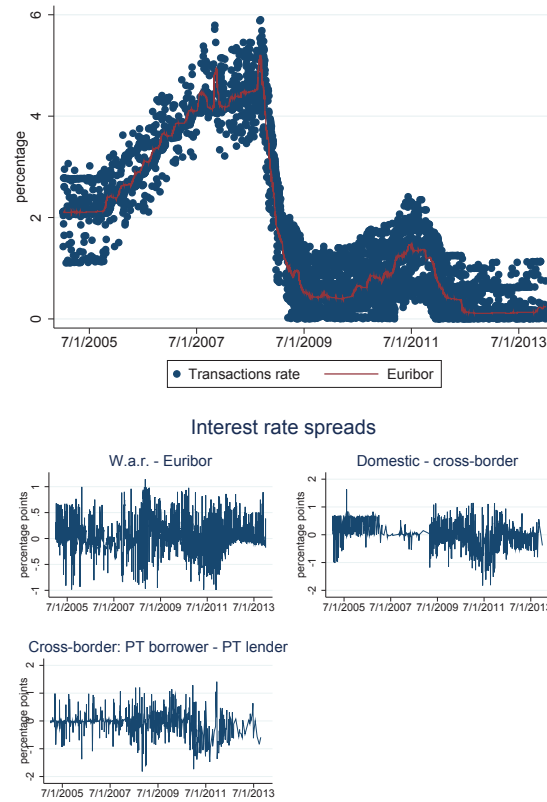


FIGURE B.4: Interest rates for one-month operations

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The euro area financial network and the need for better integration

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Abstract

When Economic and Monetary Union (EMU) was created, it was widely held that balance of payments constraints for individual euro area countries would disappear. Contrary to this dominant view, in the wake of the financial crisis, private capital suddenly stopped flowing into euro area deficit countries. Understanding why these financial constraints might emerge inside a monetary union is of crucial importance given its potential impact on resources allocation. This article finds that the euro area financial system mirrors an arrangement of relatively closed networks connected mostly through banks and governments – two sectors that are strongly interconnected, over-dependent on domestic economies and for which default is typically a complex way of satisfying their budget constraints. This structure is argued to lead to the amplification of shocks within each country. This has been observed in countries like Portugal during the recent European sovereign debt crisis. The article concludes that it is vital to mitigate the impact coming from the home bias in banks' balance sheets and consequent underdiversification on the flow of funds between institutions with excess savings and non-financial sectors in any country. Cross-border expansion, preferably following a branches model, is one possibility, however, mergers and acquisitions between banks from different euro area countries have not been very significant. In addition, the emergence of pan-european banks may increase the too-big-to-fail problem. This study suggests that asset-backed securities could be an efficient alternative to solve the problem. (JEL: D85, F34, G15, G18, G33, H63, F65)

Introduction

The first decade of the Economic and Monetary Union (EMU) saw considerable divergences in the creditor/debtor positions of euro area countries. While some countries have accumulated large external surplus positions (Luxembourg, Germany, Netherlands, Belgium), others (Greece, Portugal, Ireland, Spain, Cyprus, Slovakia, Latvia, Estonia, Slovenia

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and Italy) have accumulated a significantly negative net financial external position. This divergence has been noted in several studies since the beginning of the monetary union. The way these imbalances have been interpreted has nevertheless changed since then. As observed by Giavazzi and Spaventa (2010) and Eichengreen (2010), among others, what was at first seen as “good” imbalances became “bad” imbalances motivated mostly by bubble driven asset booms (e.g. real estate), excessive budget deficits (Schnabl and Wollmershäuser (2013)) and wrong expectations of future growth. In addition, these imbalances started to be seen as early warning indicators of future sovereign insolvency and of the fragility of the monetary union that could eventually lead to its break up. The articles cited so far focus on the economic meaning and consequences of macroeconomic imbalances. On the purely financial side, the possibility of a balance of payments crisis inside the monetary union was almost always neglected. As pointed out by Merler and Pisani-Ferry (2012), at the time of the creation of the EMU the general view was that, within a monetary union, inter-temporal budget constraints would apply to individual borrowers rather than countries. Contrary to this dominant view, private capital suddenly stopped flowing into euro area deficit countries in the wake of the global financial crisis. Simultaneously, significant creditor and debtor positions emerged in the Target2 system raising some concerns about the credit risk of these positions (Sinn and Wollmershäuser (2012)). As explained in Cecchetti *et al.* (2012), the Target2 system works in an analogous way to creating foreign exchange reserves for a country that is suffering a balance of payments crisis. In the case of full allotment refinancing, as has been the case since the beginning of the crisis, this equilibrating mechanism works automatically with a central bank liability being limited only by the amount of collateral presented by resident banks. These positions are nevertheless generally seen as undesirable in the long run, leading domestic banks to adjust their activity accordingly.

Understanding why these national level financial constraints might emerge inside a monetary union is of crucial importance given their potential impact on how resources are allocated. In this article, instead of analysing whether imbalances are good or bad (sustainable or unsustainable) or whether they were run by the public or private sectors, the focus is on the network of bilateral claims between institutional sectors (who-to-whom accounts) and what they have to tell us regarding the sudden stop in private capital flows inside the euro area. The network of who-to-whom accounts have been largely ignored, *inter alia* due to the lack of data. Nevertheless, this article shows that the euro area financial system is composed of relatively closed networks connected through external credit flows that, though significant, are led mostly by banks and governments – two sectors that are strongly interconnected, highly dependent on the performance of national economies and for which default is typically a complex process. This type of network is argued to lead to the amplification of losses inside countries, contributing

to the emergence of financial constraints at the national level and to fears of extreme events, such as a euro area break up.

This article is organized as follows. Firstly, it is shown how bilateral claims can be estimated using constrained maximum entropy. Secondly, the contribution of each institutional sector to gross external debt and the home bias in banks' balance sheets is analysed. Section three looks at the risks posed by this type of network and section four analyses how the problem can be mitigated.

Data and Methodology

The data used in this article come mostly from each country's national financial accounts (stocks), euro area accounts (stocks) and monetary and financial statistics, compiled according to ESA95. Most of the data used in this study are public.¹ Seven institutional sectors are considered: non-financial corporations (NFC), monetary financial institutions (MFI), other financial institutions (OFI), insurance corporations and pension funds (ICPF), the general government (GOV), households (HH) and the rest of the world (RoW).² Seven types of financial instruments are considered: currency and deposits, debt securities (short and long term), loans (short and long term), insurance technical reserves and other debits and credits. Equity instruments (shares and mutual funds) and financial derivatives are outside the scope of this study. All euro area countries are covered except Latvia and Lithuania.

Bilateral positions across euro area institutional sectors are not fully available. As such, this article used constrained maximum entropy in order to recover them from partial data. This estimation followed several steps. As a first step, country-level who-to-whom matrices were computed at the instrument level by using the maximum entropy method suggested by Castrén and Rancan (2013). Essentially, each bilateral claim corresponds to total claims on each instrument, k , multiplied by the joint probability of the asset being an asset of sector i and a liability of sector j . The latter, $f_{ij}^k(a, l)$, is computed simply assuming independence between the marginal distributions

$$f_{ij}^k(a, l) = f_i^k(a) * f_j^k(l). \quad (1)$$

To enhance the accuracy of the estimated bilateral relations, several constraints were then imposed using an iterative procedure that demands all

1. The data used in this study were mostly obtained in the context of the European System of Central Banks Structural Issues Report 2015 (SIR). The author would like to thank all Central Banks that provided the data.

2. MFI include the central bank and other monetary financial institutions. The decomposition between these two subsectors is not available for all countries. Data presented in this article refer to the whole sector.

accounts to be constantly rebalanced until all restrictions are satisfied (RAS algorithm).³

As a second step, country-level who-to-whom matrices were combined to form a unique euro area matrix for each instrument. Two sectors were added, notably the Eurosystem and the rest of the world (non-euro area). After overcoming some issues related with the fact that national financial accounts do not entirely match euro area accounts as computed by the ECB, the constrained maximum entropy method was again applied. Among other sources, the ECB balance sheet items database was used to impose several constraints on bilateral positions between sectors in different countries. All in all, we ended up with a 104 times 104 matrix that completely characterizes bilateral claims in debt instruments across euro area institutional sectors. The figures presented in the next section are based on this exercise.

Gross external debt and the home bias in banks' balance sheets

Figure 1 shows the contribution from each country institutional sector to gross external debt (total debt owed by a country to foreign creditors) in 2007 and 2012 as a percentage of GDP. Countries were split between lower rating (LR) and higher rating (HR) based on their current rating. Banks (MFI) and governments (GOV) account for the largest part of gross external debt in most euro area countries. Notable exceptions are Luxembourg, Ireland and the Netherlands, which act as financial centres. For these countries, other financial institutions (OFI) have a very significant contribution to gross external debt. While banks and governments play a crucial role in channelling and allocating external funds for most countries, their relative importance varies considerably between countries with no clear pattern across the two groups of countries. In 2007, the combined shares of these two sectors accounted for more than 80% of gross external debt in Austria, Malta, Greece, Belgium, Italy, Cyprus and Portugal, and for around 50% in Ireland, Slovakia, the Netherlands and Spain. If we exclude the already referred financial centres, we have that, on average (weighted), these two sectors contribute to 76% of gross external debt. In most countries, banks are by far the largest contributor to gross external debt. Greece is a notable exception, with the sovereign being the largest contributor. In Italy, the contribution of MFIs to gross external debt in 2007 was only slightly higher than that of the sovereign. The contribution from other financial institutions, including insurance companies and pension funds (OFI and ICPF), is very small in all countries except the previously mentioned

3. Estimates improve considerably with the number of constraints. The number of restrictions imposed was the highest for Austria, Slovakia, Malta, Spain, Portugal, Belgium, Slovenia, Greece, Finland and Estonia and the lowest for Ireland, Netherlands, Cyprus and the Luxembourg.

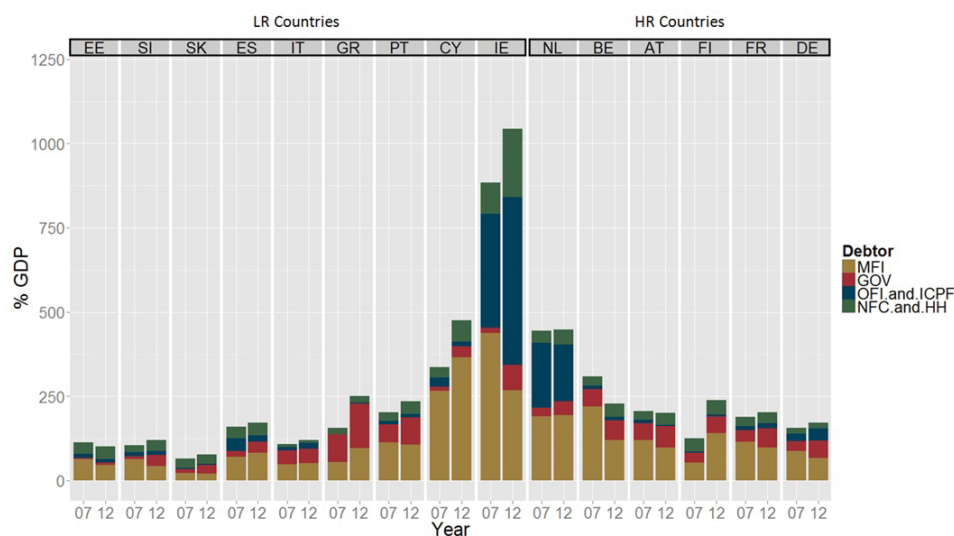


FIGURE 1: Gross external debt decomposition in 2007 and 2012.

Note: Luxembourg (HR) and Malta (LR) excluded for readability.

Source: Author calculations.

financial centres and Spain, but only in 2007. Non-financial corporations and households account for only a small share of gross external debt in most countries in 2007.⁴ From 2007 to 2012, the contribution from the government sector increased in most countries. In addition, in some countries, as is the case of Portugal, an increase in the contribution of the non-financial private sector to gross external debt was also observed.

In a context where direct relations between the non-financial private sector in each country and foreign financial institutions are residual, and therefore banks and governments account for most of the external financing, it is important to examine the latter's balance sheets closely. Whenever markets perceive significant changes in these sectors' credit risk, problems may arise on the normal flow of funds inside the monetary area. This is especially relevant given not only the possibility of sudden changes in markets expectations (some of them motivated by fears of extreme events such as redenomination risk) but also the non-linearities present in the pricing of any debt contract, which help explain sudden moves in credit markets when the debtor is not far from the default region. In the case where changes in credit risk are justified by factors that are specific to each country we may end up

4. The weighted average for the euro area is 11%. As later explained in this article, this figure would be even lower if one would exclude funding from local branches of foreign banking groups, which are considered claims from non-residents under national financial accounts.

with very heterogeneous financial conditions inside the euro area. In this context it is crucial not only to check whether these sectors are sufficiently capitalized given the type of assets in their balance sheets, but also if they are not excessively dependent on risk factors affecting mostly their home countries. In the remainder of this section, the analysis is restricted to banks as the sovereign is for obvious reasons strongly dependent on the economic performance of the country.

Figure 2 shows banks (MFI) consolidated assets (debt instruments) as a percentage of GDP in 2007 and 2012.⁵ Assets are decomposed by counterparty into five categories: i) resident NFC and HH; ii) resident OFI, ICPF; iii) the national GOV; iv) the RoW excluding the Eurosystem and v) the Eurosystem. Based on 2007, debt claims towards resident households and non-financial corporations represent the bulk of bank assets for most LR countries (more than 60%). Ireland, Cyprus and Malta are exceptions. For HR countries, the picture is more mixed. Claims towards OFI and ICPF represent less than 10% of MFI assets in all countries except the Netherlands. Claims towards the national government sector are more heterogeneous representing less than 10% of MFI assets for most countries, but almost 20% in the case of Slovakia, Italy and Greece. On average (weighted), these claims represented 7% of MFIs consolidated assets in debt instruments in 2007. Claims towards the domestic private non-financial sector clearly outweigh claims towards the national government in all countries justifying most of the home bias in banks' balance sheets. This home bias is particularly strong in LR countries. For instance, claims on residents represent more than 80% of banks' total debt holdings in Italy and Spain and more than 70% in Greece, Portugal and Estonia. Claims towards the resident sector represent less than 50% only in the cases of Luxembourg, Malta and Belgium. Notice however that these figures tend to underestimate the home bias as claims between banks from the same country are ignored.⁶ From 2007 to 2012, the home bias (private and public debt) in banks' balance sheets increased in almost all countries. This was mostly due to an increase in the share of domestic government debt holdings on banks (MFI) consolidated assets, which jumped from 7% to 12% (euro area weighted average) leading bank claims on euro area governments to increase from slightly more than 10% of their consolidated assets to 15%. The increase in the contribution of domestic government debt holdings to banks' consolidated assets was the highest in Spain, Italy and Portugal. The latter increased from 5% to 14% in the case of Spain, 18% to 26% in the case of Italy and 3% to 11% in the case of Portugal.

5. Debt instruments represent 94% of total financial assets held by MFIs in the euro area (excluding financial derivatives).

6. The consideration of unconsolidated financial accounts for this purpose could lead us to over-estimate the home bias as this would include intra-group claims and claims between commercial banks and the central bank, which were particularly significant in 2012.

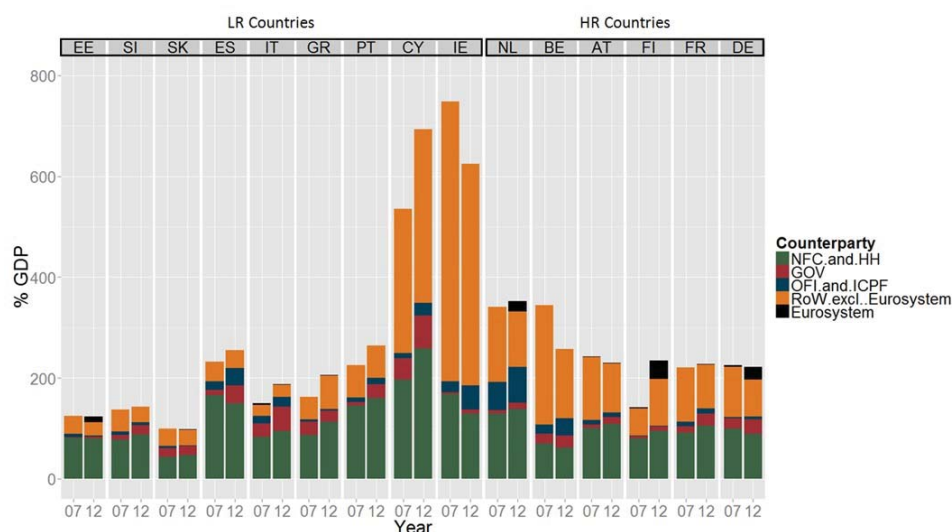


FIGURE 2: MFI consolidated assets by counterparty in 2007 and 2012.

Note: Luxembourg (HR) and Malta (LR) excluded for readability. The RoW (excl. Eurosystem) includes both euro area and non-euro area institutional sectors.

Source: Author calculations.

The network structure and the emergence of sudden stops

The previous sections have documented a network where households and non-financial corporations in each country place their savings in the financial sector (banks and other financial institutions, including insurance companies and pension funds), which distributes it either to resident sectors (non-financial corporations, households, governments and other financial institutions) – the majority in most cases – or to foreign sectors (financial sector, government or outside the euro area). In this network, and although banks are the largest counterparty of households and non-financial corporations, claims towards other financial institutions, including insurance companies and pension funds also represent an important part of households and non-financial corporation's portfolio of financial assets. Looking at gross external debt figures, however, one observes that banks, a sector with a clear home bias in its balance sheet, are responsible for most of the gross external debt. This is what one would expect given that banks run their activity mostly locally, while other financial institutions invest more in international capital markets, which are not open to small and medium enterprises and households. In order to understand why this type of network leads to the amplification of losses, one needs to first understand how each agent fulfils its inter-temporal budget constraint. Essentially, in an economy where

monetary financing is not allowed, either governments, banks, households or corporations have three ways to fulfill their budget constraint: increase revenues, reduce costs or default. For those households and corporations that are not able to either increase revenues or reduce costs, default is a frequent outcome. There is legislation able to deal with these situations and the impact of default is foreseeable. This contrasts with banks and sovereigns, for which default is typically more complex and has wider impact. In the case of banks, and given their strong interconnections, the default of one bank may lead other banks to default, creating a domino effect in the economy, or at least generating economic uncertainty. In addition, as noted by Bernanke (1983), bank failures end up having a considerable effect on the real economy because customers of funds are bank dependent and bank failures tend to occur during deep recessions when customers need them the most. In the case of the sovereign, the problem is even greater as there is no law or court for settling sovereign defaults. This is particularly important given that as opposed to firms and households, it is hard to define what are the limits on what a sovereign state can pursue in terms of fiscal policy in order to fulfill its commitments, which raises uncertainty even further.

Now, consider a scenario where either non-financial corporations or households in one country start defaulting substantially more than expected. If this debt is mostly held by poorly-diversified resident banks, as we have seen to be the case in most euro area countries, this will ultimately lead to a deterioration in these banks' risk profile. Either because the initial shock affected most of the banking system or simply due to the strong interconnections in the domestic financial sector, the initial shock may end up affecting the whole banking sector and even the government sector given the so-called implicit guarantees that may evolve to a bail out decision. This may lead to a deterioration of the risk profile of the government, which may decide to take fiscal measures affecting all other sectors balance sheets and economic growth. The latter would affect again the banking sector through its holdings of both public and private debt. This mechanism is known in the literature as the sovereign-banks feedback loop (Figure 3A) and has been well documented both in the theoretical and empirical literature.

The above described balance sheet mechanisms also have significant consequences in terms of financing. This is particularly true in the case of households and small and medium sized enterprises (SMEs), which are not able to borrow externally and thus fulfill most of their financial needs through the resident banking sector. The worse the risk profile of the banking sector, the higher should be the cost of funding for banks and for their customers. In the limit, banks may not be able to roll over their debt at a reasonable price leading to the appearance of severe quantity restrictions in credit flows in the economy. These price/quantity restrictions may lead to a higher number of defaults than otherwise. This often creates a credit supply problem on top of a demand problem further limiting consumption, investment and future output

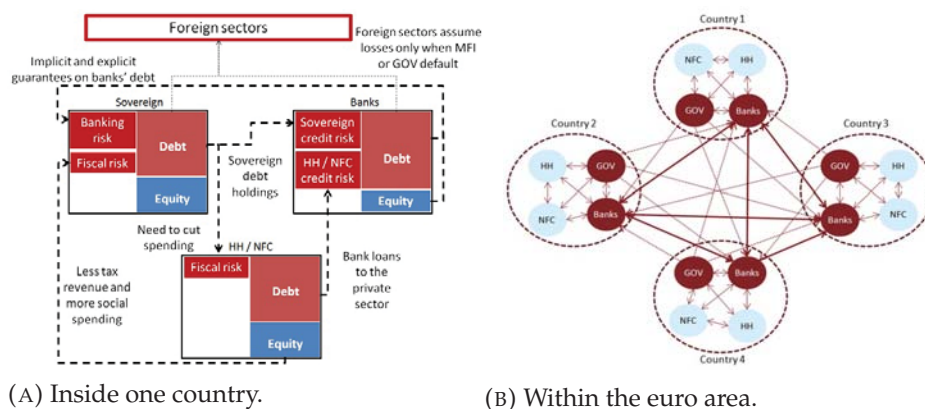


FIGURE 3: Shock transmission.

Notes: The arrows indicate shock/loss propagation. Not all channels of shock transmission referred in the article are represented. Other financial institutions, including pension funds and insurance companies do not appear on these figures for readability reasons. The figure on the right hand side illustrates the network of bilateral claims in the euro area as an arrangement of small worlds connected by banks and sovereigns.

growth. This is especially relevant given that during a sovereign debt crisis banks tend to increase their holdings of domestic sovereign debt crowding out loans to the private sector.⁷ How these restrictions take place should depend however on the funding structure of the banking system and on banks' capacity to quickly deleverage, selling their assets instead of cutting credit. In the cases where the banking system is substantially financed through short term market instruments, which had been the case in the years that preceded the financial crisis, these restrictions should emerge faster as banks become more susceptible to sudden changes in markets expectations. Some of these changes in expectations may be already partially a consequence of the mechanism here explained, as is the case of redenomination risk. As pointed out in the bank lending channel literature, the fact that banks are badly capitalized should end up affecting households/firms with good and bad risk profile, leading to an unlevel playing field in terms of competition inside the same monetary area, further contributing to the persistence of real negative effects and fears of extreme events, such as a euro area break up.

The literature has emphasized that the banks-sovereign feedback loop is particularly destructive in the euro area. Several reasons have been pointed out, notably the lack of fiscal and monetary shock absorbers and the institutional setting of bank supervision and resolution. In this article, we

7. See Gennaioli *et al.* (2014) and Battistini *et al.* (2013) for an analysis of the reasons behind this behaviour.

argue that on top of this, the network of bilateral claims in the euro area also contributes to the enforcement of this link and to the consequent fragmentation of the financial system. Despite the huge progress in terms of financial integration in the first years of the monetary union, the euro area financial system currently mirrors an arrangement of relatively closed networks, where countries borrow from foreign savers mostly through their banking system and to a lesser extent through the sovereign sector. In such type of networks, foreign sectors assume the credit risk in each country only through banks and sovereigns, two sectors that are not geographically diversified and for which default is particularly hard and complex. In this network each country resembles a “small world” (Figure 3B) where losses tend to be kept generating feedback effects, instead of being exported to the rest of the world. As they are kept, they tend to affect a higher number of agents until being effectively fully absorbed. We illustrated above some ways agents are affected, notably through balance sheet contagion and credit channels. If the initial losses were instead exported to the rest of the world, they would dissipate faster given the lower correlation that foreign sectors have with the initial shock. In this case, foreign sectors would simply take on the losses corresponding to the risk for which they were previously paid. If we think of these foreign sectors as being foreign banks, this would replicate quite well what happens inside a euro area country when problems arise in one region. Notice also that this problem would not be so significant in networks where the sovereign has monetary autonomy. In these cases the sovereign works as an absorbing node receiving the shocks but not propagating them.

The need for a better type of financial integration

In this context, it is vital to approximate those sectors that are creditors and those that are debtors from a euro area point of view without putting in question the role of the banking system as the main financial intermediary in the economy. In other words, it is necessary to mitigate the impact coming from the home bias in banks’ balance sheets on the flow of funds between institutions that hold excess savings and non-financial sectors in any country that has good investment projects. Generally, this can be done through direct cross-border flows (e.g. bonds placed in international capital markets) to debtor countries non-financial private sectors or through cross-border expansion of banks. The latter has been referred to in the literature (see Allen *et al.* (2011)) as a better model of financial integration not only because it benefits a larger number of sectors in the economy (e.g. households and SMEs), but especially because the building up of a foreign retail network is usually associated with a higher level of commitment with the host country’s economy. This expansion can be done either opening branches in foreign countries or through subsidiaries. According to European legislation

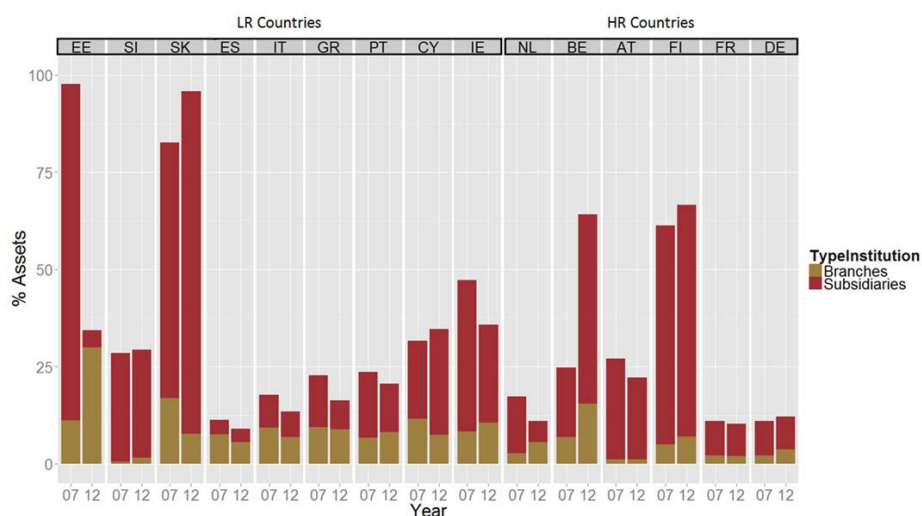


FIGURE 4: Market share of foreign bank branches and subsidiaries in euro area member countries in 2007 and 2012.

Source: ECB.

any bank that has a banking license in one member country can open a branch in any country in the European Union, making it the easiest way to expand cross-border. Notice however that bank branches are not legally independent entities and thus, from a national financial accounts point of view, their assets belong to their parent banks, making it impossible to distinguish them from direct cross-border flows. In contrast, a subsidiary is an autonomous bank held by a foreign banking group, whose assets are considered to belong to the resident monetary sector (MFI). As such, one may argue that, though resident banks are not diversified, in the sense that they have a home bias in their balance sheets, they may belong to major banking groups that are present in several countries and are thus potentially geographically diversified. Figure 4 show us however that the market share (% of total assets) of foreign bank subsidiaries and branches remains minor in most countries. In fact, despite European Commission pressure to break down barriers to cross-border integration, M&A operations have remained subdued and dominated by domestic market consolidations. This contrasts with the United States where the M&A market have been more dynamic both intrastate and interstate (see Garcia, 2009).

The building up of the banking union in the United States is a good comparison for the euro area. Interstate activity in the United States was severely limited until the 1980s, when it became easier for banks to establish subsidiaries but not branches in different states. According to Garcia (2009),

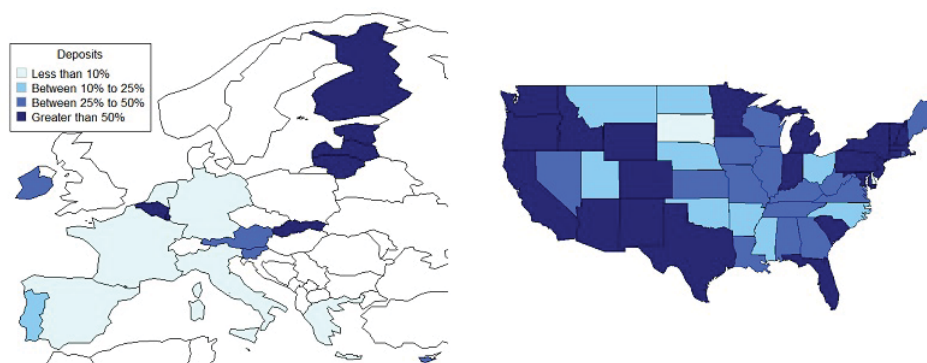


FIGURE 5: Share of deposits in foreign subsidiaries and branches in euro area countries and share of deposits in branches owned by out-of-state institutions (interstate branches) in the United States in 2013 and June 2014, respectively.

Source: ECB and FDIC.

from 1979 to 1994, the asset share of out of state multi-bank holding companies increased from roughly 2% of bank assets in the United States to near 30%. Only with the reforms made in the 90s did banking groups start to convert many of these subsidiaries into branches in order to maximize their efficiency. Figure 5 compares the share of deposits in foreign subsidiaries and branches in euro area countries with the share of deposits in interstate branches in the United States.⁸ Figures for the United States are considerably higher. In particular, interstate branches are responsible for more than 50% of deposits in all major U.S. states, while in Europe foreign subsidiaries and branches in bigger countries such as Germany, France, Italy and Spain account for less than 10% of all deposits. The lower level of financial integration at the retail level in the euro area is particularly noteworthy given the greater relative importance of the banking system. Questioned on the reasons for this in 2005, euro area bankers have claimed that synergies for cross-border banking are thwarted by the lack of uniformity across member countries in terms of prudential supervision, taxation, culture, language, legislation and political interference.

As at first happened in the United States, cross-border expansion in the euro area has been done mainly through subsidiaries (Figure 4). From the regulators' perspective, this system allows the home country regulator to avoid becoming responsible for guaranteeing deposits in foreign countries. From the bank's point of view, though expansion through branches is more

8. As far as I know there is currently no data available on the share of assets held by interstate bank branches per state.

cost-efficient and allows a more centralized risk management, expansion through subsidiaries limits the impact of a potential failure. On this point, de Haas and van Lelyveld (2011) found that bank subsidiaries usually contribute to the stability of credit growth in host countries, but that the latter did not occur during the Great Recession. In fact, during a severe crisis, since the bank has limited liability, it may be optimal for it to leave its subsidiary instead of continuing to inject capital or lend to it. The fact that shareholders have limited liability is far from irrelevant for risk transmission. In the event that a local subsidiary does not have enough assets to meet its commitments, someone may have to bear the losses. Similar to any other domestic financial institution, these could be the bondholders, but also the national resolution fund or the national deposit insurance mechanism, potentially contributing to the reinforcement of the sovereign-banks link. This contrasts with foreign bank branches, which are not legally autonomous institutions and thus cannot default separately from the parent bank. Within subsidiaries, Lehmann and Nyberg (2014) emphasize the different approaches followed by different banking groups regarding their subsidiaries. For instance, following Bank of Spain “framework for good practices”, Spanish banking groups show among the highest degrees of reliance on host country funds and the lowest shares of intragroup funding.⁹ This limits the benefits of cross-border banking as subsidiaries become less able to channel funds between countries becoming as procyclical as domestic banks. In addition, note that the lack of a parent guarantee on subsidiary liabilities make these banks similar to other domestic institutions also in terms of their borrowing costs. In contrast, Austrian and Italian banking groups are found to follow a more centralized approach, more similar to what would happen when a bank opens new branches. The fast conversion of out of state subsidiaries into interstate branches in the United States suggests that the efficiency benefits of the branches model are considerable and that this should be the expected outcome once all barriers vanish.

Though most trends point to further cross-border consolidation in Europe, Schoenmaker (2015) concludes that it may still take some time before a significant cross-border wave such as the one observed in the United States takes place. In fact, some of the reasons previously referenced by banks for not expanding their retail activities are still valid, even after the creation of the banking union. This is the case of regulatory barriers. In this regard, each country is still responsible for emergency liquidity assistance to its banking system (ELA) through its national central bank; the deposit guarantee scheme has been harmonized, but risk has not been mutualised; and the resolution mechanism will remain in a transition phase for 8 years. The lack of a common deposit guarantee scheme is frightening not only because it maintains the

9. Please refer to Bank for International Settlements (2010).

sovereign-banks link but also because it creates a kind of stigma around cross-border expansion through bank branches. Regarding the single resolution mechanism, and though it foresees a gradual mutualisation of the potential costs of bank resolution, there remain some doubts on how it will work in practice in an acute crisis. According to Lehmann and Nyberg (2014) the resolution-making process is still complex and not so transparent, which is the result not only of member states trying to limit the risks to national budgets, but also the different national legislations that are not harmonized. In addition, given the overall capacity of the single resolution fund (1% of covered deposits), the existence of a fiscal backstop is essential. In this regard the banking union foresees the possibility of the European Stability Mechanism making direct bank recapitalizations. For this purpose, a burden sharing scheme has been designed. The latter is nevertheless very far from mutualising all risks. In light of this, it is to be expected that regulators keep their ring-fencing behaviour (informally requesting banks to open subsidiaries rather than branches and to lend or invest in the same country where deposits are collected), diminishing banks' willingness to expand retail operations across the euro area.

As the ECB takes the lead in bank supervision in the euro area, some of the barriers mentioned before are expected to disappear. Nevertheless, as pointed out by Schoenmaker (2015), authorities, including the ECB, may be wary of permitting the creation of too-big-to-fail banks, avoiding consolidation among banking groups that are already very big as already occurs in the United States. According to the Financial Stability Board (2014), the banking union includes 9 out of the 30 banks considered as global systemically important. Given their size and experience, these are probably the banks better prepared for further international expansion. Major banks in the banking union show nevertheless market shares clearly below their United States peers suggesting there is considerable space for further cross-border integration. According to Schoenmaker (2015), while JPMorgan and Bank of America have market shares in the United States of 13% and 11%, respectively, Credit Agricole, the largest bank in the banking union, ranking by euro area assets, has a market share of only 5%. This leads us to conclude that a similar wave of cross-border mergers and acquisitions in Europe, such as the one that occurred in the United States, should lead to a considerable increase in the number of systemically important banks in the euro area. All in all, we conclude that cross-border expansion preferably through bank branches can help mitigate the network problem identified. Nevertheless, this process is expected to take some time if left to banks' willingness to expand abroad. On top of prudential reasons, banks may simply believe it is not efficient to expand given all other factors before mentioned. In addition, the fear of too-big-to-fail institutions may also overwhelm regulatory interest in the development of a market composed by mega banks.

The above mentioned arguments lead us to think that effort should be made in order to find alternative ways to avoid the concentration of risks inside each country. The introduction of the bail-in principle in the Single Resolution Mechanism goes in this direction by allowing creditors, independent of their origin, to suffer losses and thereby “automatically” recapitalise banks without necessarily closing them in cases where shareholders are not able to raise capital. The creation of a single deposit guarantee scheme in the banking union, sovereign debt mutualisation or any other type of insurance across euro area countries would go in the same direction. Nevertheless, these are matters where it has been difficult to reach an agreement. For these reasons, further attention should be given to asset-backed securities (ABS). Whenever the right regulatory incentives are given (i.e. banks’ incentives to monitor credit quality should not be eliminated), ABS may be an efficient way to connect final debt holders (households and corporate) and financial institutions with excess savings (not only banks), largely in net creditor countries, surpassing the problems posed by the balance sheet intermediation of underdiversified resident banks. The benefits are considerable. Apart from reducing risks in banks’ balance sheets (through further diversification), ABS avoid the amplification of risks inside a country whenever problems arise, addressing the network problem identified in this article. As banks become more diversified across the euro area, they should become less sensitive to asymmetric shocks, limiting lending volatility and improving monetary policy transmission. Consider the case of a bank from a particular country faced with a country specific shock. Further consider that the balance sheet of this bank is composed by equity tranches from its own ABS and by senior and/or subordinated tranches of ABS produced by banks from other euro area countries in addition to other assets such as sovereign debt holdings or unsecuritized loans (Figure 6). Whenever the benefits from geographical asset diversification mentioned here are internalized in regulators capital requirements this could be a reality.¹⁰¹¹ This bank is clearly less vulnerable to a country specific shock than a bank that holds only loans to resident sectors both in terms of capital and funding. The fact that this bank holds a considerable amount of foreign assets, which may not be devaluated or downgraded during a more acute crisis, helps the bank deleverage (if needed) and smooths the process of obtaining funding,

10. In the limit, one can also hypothesize the emergence of financial institutions that collect deposits, but only invest in securitized loans.

11. Whether a significant proportion of banks’ balance sheets is suitable for securitization is an interesting question, though. While in the case of mortgage backed securities it is relatively straightforward for investors to evaluate what they are buying, in the case of loans to SMEs, problems related with asymmetry of information turn more relevant. Common guidelines on a minimum level of balance sheet information, proper ABS calibration and risks to bank credibility may help avoiding that banks end up pumping bad loans through these products, though.

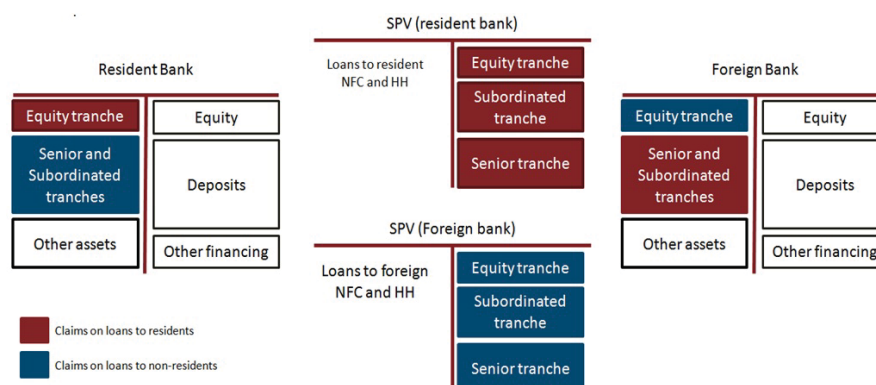


FIGURE 6: Using ABS as a way to promote geographical portfolio diversification in banks' balance sheets across the euro area.

Notes: Resident banks grant credit to households and non-financial corporations and place these loans on special purpose vehicles that issue securities that represent claims on these loans. Resident banks retain the equity tranche from these securitizations and place the senior and subordinated tranches in the market. Retention is essential to maintain banks' incentives to monitor credit quality. The foreign bank does the same. As long as regulators give incentives to geographic portfolio diversification it is plausible to think that resident banks will end up buying ABS issued by foreign banks.

either from the markets or from the ECB. This contrasts with what occurred during the recent financial crisis, where several banks faced with growing capital requirements and high costs of funding had to quickly deleverage by cutting credit in order to avoid further shareholder dilution. Notice also that ABS allows even small banks across the euro area to obtain the benefits from international asset diversification without needing to expand abroad, which may not be an efficient option for these banks. Finally, it is interesting to note that an agreement regarding the creation of a single deposit guarantee scheme should become substantially easier to obtain once banks across the euro area finance agents across the whole euro area.

In spite of all these advantages, the ABS market in the banking union has been sluggish since the peak reached in 2007 (Figure 7). In addition, as opposed to past practices, the majority of all new issuances have been retained by the originator bank instead of being placed in the market pre-empting a better distribution of risks across institutions. Altomonte and Buzzoli (2014) note that in the aftermath of the crisis, the practice of slicing and dicing of loans into ABS packages was blamed for starting and spreading the crisis through the global financial system. Regulation across financial institutions since then has become particularly unfavourable towards this type of products. Literature has noted however that it was the over deregulation that occurred in the United States (e.g. lack of incentives to monitor credit quality)

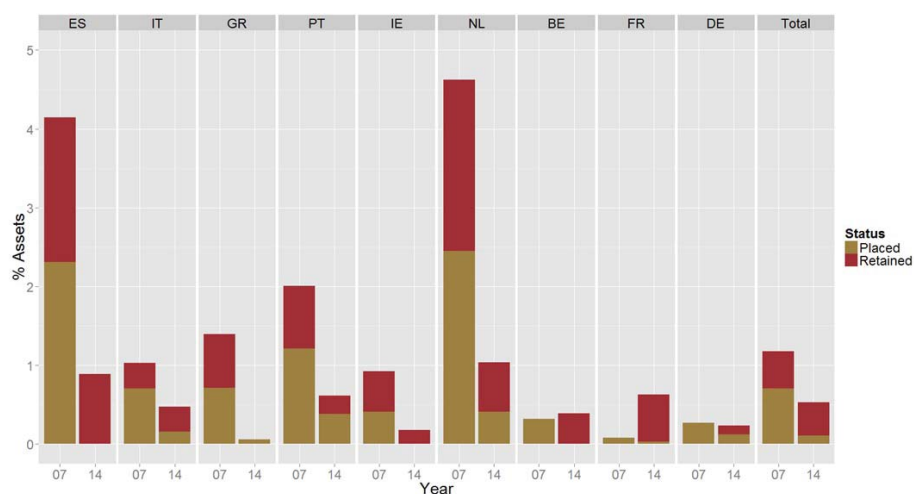


FIGURE 7: ABS issuances in 2007 and 2014 (% total MFI assets, excluding the European System of Central Banks)

Source: SIFMA

that is to blame for the 2008 financial crisis and not the ABS itself, which has even contributed to avoid further accumulation of losses inside the United States.

There are however some signs that the regulatory conditions around the ABS market might be changing. Recently, the ABS market has been seen by the ECB and the Bank of England as a way to improve the efficiency of resources allocation and to allow better risk sharing with impact on credit market conditions, monetary policy transmission and economic growth (see European Central Bank and Bank of England (2014a) and European Central Bank and Bank of England (2014b)). Though the benefits of ABS are increasingly being recognized, the fact that this instrument can be very useful in mitigating the sovereign-banks feedback loop and the small world pattern that characterizes the euro area financial network has not been very much emphasized. Apart from the creation of the banking union, recent action, including the purchase of ABS by the ECB, has focused on mitigating the symptoms of financial market fragmentation (e.g. differences in bank loans spreads) rather than its causes. As opposed to other measures under implementation, the development of a well functioning ABS market could be a way to overcome the fragility identified in the euro area financial network and its implications on financial fragmentation, maintaining the benefits from bank intermediation. By simultaneously mitigating the concentration of risk and losses in each country and by increasing bank's balance sheet liquidity, this article argues that the latter contributes to avoiding micro problems from

becoming macro problems, easing the deleveraging process currently faced by many banks across the euro area. This would be particularly important in the current transitional phase where the construction of the banking union is still incomplete, cross-border bank branching is still incipient and credit growth is weak. The benefits noted in this article have not been fully acknowledged by policymakers, who continue to over-penalize the ABS market vis-à-vis other asset classes.

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A Reappraisal of Eurozone Countries Output Differentials

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Abstract

In this paper, we use the concept of real convergence (considering the stationarity of per capita cross-country output differences) and present updated evidence on the persistence properties of output differential data, accounting for the potential occurrence of persistence changes. We focus on per capita output differences for 14 Eurozone countries over the period 1950-2015. Results suggest that the gap between the central and northwestern countries has been reduced through persistent convergence paths. However, the convergence path of the southern countries to the central and northern countries seems to have been interrupted. (JEL: C12, C22, O4)

Introduction

Economic convergence constitutes a central goal of the European authorities as it is a key factor for the success of the single monetary policy and to achieve per capital real income convergence. In 1992, the Maastricht Treaty set the convergence criteria which the member states should accomplish before adopting the single currency. Meanwhile, several policy tools were in place directed to improve the economic integration of the less developed countries. These have been the recipients of structural funds aimed at increasing competitiveness and reducing income disparities within the European Union (EU), achieving thereby economic and social cohesion among the member states. Several countries have also adopted structural policies toward economic integration over the last decades, which include the liberalization of capital and labor markets and the creation of the European Economic and Monetary Union (EMU).

Although the issue of real convergence is central for the success of the European Union, neither economic theory nor empirical evidence available have provided an unambiguous proof for its existence among the European

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member states. This divergence of results follows, in general, the lack of consensus that characterize the two main branches in the literature. On the one hand, the neoclassical growth theory (Solow, 1956; Mankiw *et al.*, 1992) predicts conditional convergence between lesser developed and developed countries. According to such models, real per capita output can rise with increases of the stock of capital available to each worker and technological progress. Given identical technologies, and identical structures, countries will converge to identical steady states and the mechanism behind convergence is based on diminishing capital returns: countries far away from their steady states, with lower capital per worker and lower per capita incomes, will exhibit higher growth rates and thereby the catching up process is activated. On the other hand, the New Growth Theories, starting with Romer (1986) and Lucas (1988), state the lack of convergence between lesser developed and developed countries in practice due to inconsistencies that motivate reduction of capital earnings in the former countries.

The absence of consensus on economic convergence has motivated an intense debate on the question of cross-country per capita output convergence, from which a vast theoretical and applied literature has emerged. The huge variety of results is partially explained by differences in data, countries, sample periods and methodologies. Recent references that illustrate such disparity of results include, *inter alia*, Azomahou *et al.* (2011), Beyaert and García-Solanes (2014), Cuaresma *et al.* (2013), Palan and Schmiedeberg (2010), Crespo-Cuaresma and Fernández-Amador (2013), Kutan and Yigit (2009), Monfort *et al.* (2013), Iancu (2009) and Mihuț and Luțăș (2013). Azomahou *et al.* (2011) suggest that there has been no convergence among developed countries. Beyaert and García-Solanes (2014) and Crespo-Cuaresma and Fernández-Amador (2013) suggest that the convergence process is vulnerable to business cycles. For Cuaresma *et al.* (2013) and Kutan and Yigit (2009), the investment in human capital is a decisive key for convergence. Palan and Schmiedeberg (2010) develop a sectorial study and show evidence of divergence in technology intensive manufacturing industries. Divergence is also found in Monfort *et al.* (2013) in which two convergence clubs in the EU-14 were identified. Iancu (2009) also detects an increase of divergence in Europe over the period from 1995 to 2006, whereas Mihuț and Luțăș (2013) assess the Sigma (σ)-convergence across the new EU member states. Other references exploring convergence of transition countries to the EU level are, *inter alia*, Kocenda (2001), Kasman *et al.* (2005), Kutan and Yigit (2009) and Matkowski and Prochniak (2007).

All these studies follow the research lines of the early studies on the convergence of countries and regions, which were based on simple cross country regressions (see e.g. Baumol, 1986, DeLong, 1988, Barro, 1991, Levine and Renelt, 1992, Barro and Sala-i-Martin, 1992 and Mankiw *et al.*, 1992). Other reference studies such as Barro and Sala-i-Martin (1991, 1992) evaluate the

concepts of Beta (β)- and σ -convergence (see Appendix A for a set of empirical results using these measures).

Following several criticisms to cross-sectional approaches to evaluate real convergence (see, *inter alia*, Quah, 1993; Evans, 1998; and Bernard and Durlauf, 1995) recent studies make use of time series-based concepts. These include the use of panel unit root tests to evaluate stochastic convergence and to test whether shocks have temporary or permanent effects on income differentials (see Ben-David, 1996; Koeenda and Papell, 1997; Kocenda, 2001; Evans and Karras, 1996; Lee *et al.*, 1997; and Holmes, 2002). Other studies report results based on principal components methods (see Snell, 1996), and on cointegration in a VAR framework as developed by Bernard and Durlauf (1995), which became a reference for many subsequent studies in the field (see e.g. Greasley and Oxley, 1997; and Mills and Holmes, 1999).

In this paper, we evaluate real convergence between 14 European countries based on their per capita output differences, both from a group convergence perspective as well as from an individual country's perspective. We adopt a time series framework to test for per capita output convergence which, as shown by Evans (1998), provides a better approach to test for convergence than cross-section analysis. Following recent literature, we build on the notion of cross-country output convergence initially proposed by Bernard and Durlauf (1995, 1996) and used recently in Pesaran (2007), which shows that for two countries to have converged it is necessary that their output differential is a stationary process, irrespectively of whether the individual country's output series are trend stationary and/or contain a unit root. Moreover, to analyse output convergence across a large number of countries without being subject to the pitfalls that surround the use of output differentials measured relatively to a particular benchmark country, we consider the properties of all possible real per-capita output differentials.

We approach the analysis of convergence based on the analysis of nonstationarity and persistence change of per capita output differentials among countries, which take into consideration possible structural changes in the data. Moreover, we investigate whether the output differentials within the group of EU members have stabilized over the sample period.

The structure of the paper is as follows. Section 2 introduces the notion of convergence. Section 3 presents the data and the empirical analysis of per capita output differentials, and section 4 provides some concluding remarks. An appendix collects the tests for persistence change used in the paper.

Notion of Convergence

Traditionally, convergence analysis has been developed in the literature based on the analysis of cross-section correlation between initial per capita levels and subsequent growth rates for groups of countries. A negative correlation

is taken as evidence of convergence as it implies that, on average, countries with lower per capita incomes are growing faster than countries with higher initial per capita incomes. This cross-sectional approach is often encapsulated in the notion of Beta (β)-convergence, which requires that lesser developed countries grow faster than developed ones. However, several criticisms have been raised against the conclusions reached in many of these studies on the account of "Galton's fallacy"¹.

In contrast, we employ a time series approach which builds on a stochastic definition of convergence where per capita output differentials are expected to be stationary. Moreover, temporary shocks to key structural variables such as saving rates, population growth, and technological progress are characterized by stationary relative outputs thereby indicating that economies are stochastically converging. This means that the convergence definition followed in this paper considers the behavior of output differentials between pairs of economies over the sample period. This procedure is based on a probabilistic definition of convergence and the idea behind this is that the time-series properties of all possible countries' output differentials are examined by means of unit root and persistence change tests. These tests interpret convergence to mean that per capita output differentials are always transitory in the sense that long-run forecasts of the difference between any pair of countries converges to zero (Bernard and Durlauf, 1996) or to a tolerable constant value (allowing for convergent economies to have different endowments, saving rates or population growth rates, as suggested in Pesaran, 2007) as the forecast horizon grows. Convergence, according to this approach has the strong implication that per capita output differences between any two economies cannot contain unit roots or time trends.

To illustrate the approach consider the log-linearised output of country i as (see Lee, Pesaran and Smith, 1997) ,

$$y_{it} = c_i + g_i t + u_{it} + \eta_t \quad (1)$$

where c_i is a fixed effect, $g_i t$ is a deterministic trend component, $\eta_t \sim iid(0, \sigma_\eta^2)$ is a common shock and $u_{it} = \varphi_i u_{i,t-1} + \varepsilon_{it}$ is an idiosyncratic component that is assumed to be autoregressive (AR).

1. According to Galton's fallacy, the regressions to estimate Beta-convergence, which relate growth rates and initial levels of output do not provide complete information about the output distribution among countries because they are regressions towards the mean. In fact, if there is evidence of a negative relationship between initial output levels and growth rates, that relationship occurs on average and does not necessarily mean that there has been a reduction of output dispersion. Because of this, Galton's fallacy recommends to focus at economic relationships beyond the conditional mean.

Hence, given (1) the output differential of countries i and j at time t is defined as,

$$\begin{aligned}
 x_{ij,t} &= y_{it} - y_{jt} \\
 &= (c_i - c_j) + (g_i - g_j)t + (u_{it} - u_{jt}) \\
 &= \delta_{ij} + \gamma_{ij}t + v_{ij,t}
 \end{aligned} \tag{2}$$

where $\delta_{ij} = c_i - c_j$ is a fixed effect that depends on the initial conditions in countries i and j , $\gamma_{ij}t = (g_i - g_j)t$ is a deterministic time trend component which is equal to zero if the growth rates of technology in countries i and j are equal, $g_i = g_j$, and $v_{ij,t} = u_{it} - u_{jt}$ is a stochastic component.

Equation (2) represents the framework typically used to test for convergence between countries i and j . If the trend is not statistically significant ($H_0 : \gamma_{ij} = 0$) and the output differential $x_{ij,t}$ is integrated of order zero (stationary) then economies i and j converge at an exponential rate, as implied by a standard stationary AR process and remain on similar paths afterwards. Hence, for this concept of convergence to hold we must observe that, *i*) $v_{ij,t} \sim I(0)$ and *ii*) $\gamma_{ij} = 0$ (see e.g. Pesaran, 2007).

For illustrative purposes consider the following graphs which represent the log of per capita output of two fictitious countries:

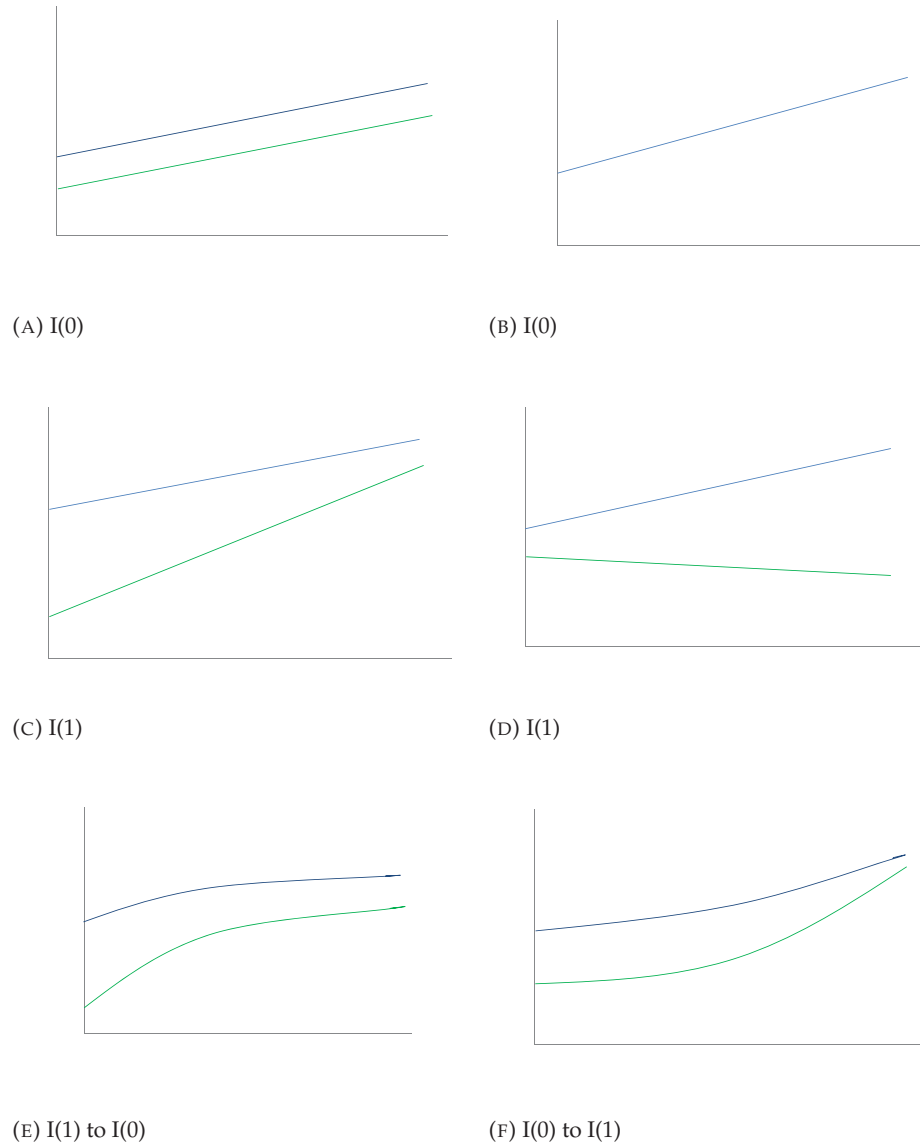


FIGURE 1: Illustration of notions of persistence

Hence, the concept of log per capita output convergence allowed by (2), i.e., the null hypothesis considered (that the output differential $x_{ij,t}$ is stationary and that its trend is not statistically significant) corresponds to the behaviour displayed in graphs A) and B), whereas rejection of this null hypothesis by traditional unit root test procedures (or trend stationarity of the series) implies output differential behaviour of the type displayed in graphs C)

and D). One contribution of our analysis is that, through the use of persistence change tests we also allow the behaviour of countries' output differentials to change from stationary to nonstationary or vice versa, as displayed in graphs E) and F). Note that the behaviour patterns displayed in C) and E), and in D) and F) are different in nature since in E) and F) there are periods during which the output differential is stable (in graph E) this would correspond to the first part of the sample, whereas in graph F) it is the second part), which is not observed in C) and D). An interesting property of the procedures used in this paper to test for persistence change is that once the persistence change is detected it allows to discriminate whether the change is from stationarity to nonstationarity (as suggested in graph E) or vice versa (as suggested in graph F)).

In the procedure used in this paper the change in persistence is endogenously considered and therefore the timing of the change (or changes) is determined by the procedure and not exogenously imposed. Moreover, given the small sample sizes considered in the empirical analysis we only allow for at most one change in persistence.

Empirical Analysis

Data description and sources

The data used in our analysis consists of annual observations of per capita output for a total of 14 European countries: Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal and Spain. The source of this data is The Conference Board Total Economy Database™, May 2015 (<http://www.conference-board.org/data/economydatabase>).

Figure 1 illustrates the evolution of the log of real per capita output from 1950 to 2015 for the 14 countries under analysis. For the purpose of analysis we consider two groups of countries. Group I is composed by the central and northwestern European countries (Austria, Belgium, Finland, France, Germany, Ireland, Luxembourg, and the Netherlands); and Group II includes southern countries (Cyprus, Greece, Italy, Malta, Portugal and Spain).

Although upward trends are noticeable from Figure 1, reflecting a positive annual average growth, the data also indicates the consequences of the recent financial crisis on per capita output of all countries, but in particular in southern countries, which are reflected in a pronounced slowdown or even an effective reduction by the end of the decade.

The lower growth of per capita output is not independent from the evolution observed in the labor markets. Over the period under analysis all countries experienced reductions of the number of working hours (see Figure 2). Such reductions are particularly pronounced in the first group. Given

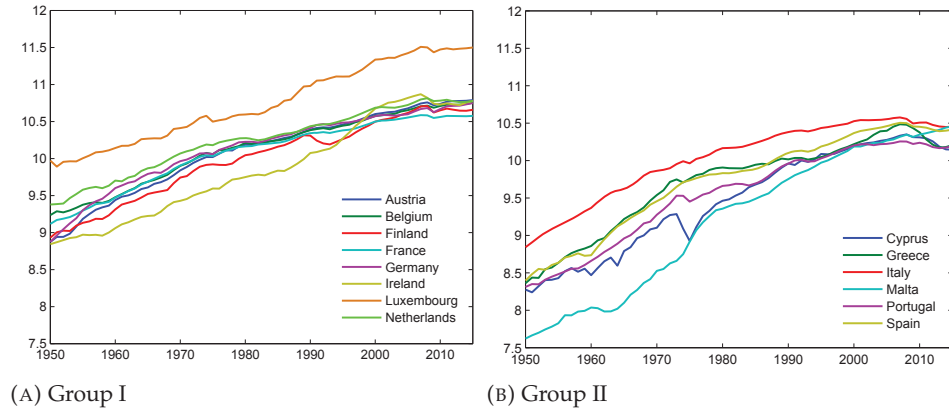


FIGURE 2: Log of Real per capita Output.

Source: The Conference Board Total Economy Database™

this variability in the working hours over time, real per capita output and labor productivity should not be used indiscriminately, as labor productivity turns out to be an alternative measure of convergence which is achieved through technology advances that spread out across countries. This negative evolution in the labor market reflects the negative effects of the financial crisis on the potential output, due to reductions of the productive capacity of these economies, as a result of reductions in demand motivated, *inter alia*, by reductions in investment.

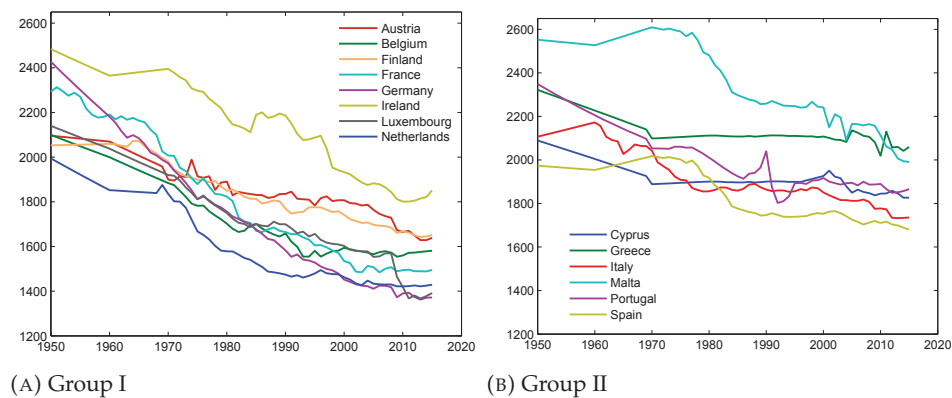


FIGURE 3: Annual hours worked per worker.

Source: The Conference Board Total Economy Database™

Over the last decades, all economies experienced a slowdown of labour productivity, being this particularly observed in Group II when compared to Group I. Although there have been improvements over time it seems that the differential between the countries in Group I and in Group II has in general not been bridged yet.

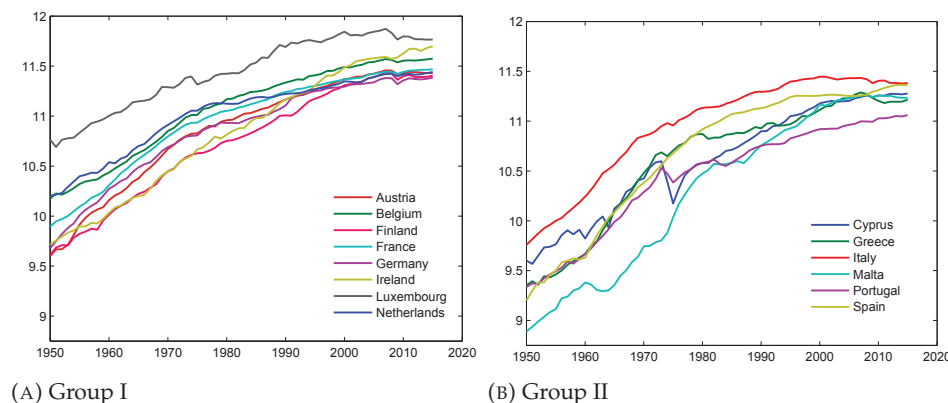


FIGURE 4: Output per worker in 2014 US\$.

Note: Data is converted to 2014 price level with updated 2011 PPPs. Source: The Conference Board Total Economy Database™

Labor productivity can also be measured in terms of hours worked. This definition of productivity is particularly informative as the evolution of the number of working hours follows closely the economies' business cycles. As expected, Figure 4 shows that labor productivity per hour worked in Group I is generally higher than in Group II, and a slowdown is again observed over the last years in all countries as a result of the 2008 financial crisis.

Output differentials of European economies in the period 1950-2015

For a country by country analysis of convergence, in this section we evaluate the per capita output differentials as suggested in Section 2. Considering the log-linearised output of a country as given in (2), the time series notions of convergence imply that per capita output disparities between converging economies follow a stationary process. Therefore, divergence is related to the unit root hypothesis (or trending differentials) in relative per capita output. To analyse the properties of per capita output differentials across these economies, we consider the log real per-capita output differences of countries i and j , $y_{it} - y_{jt}$, $i = 1, \dots, N - 1$, and $j = i + 1, \dots, N$, over the period from 1950 to 2015. Hence, we consider a total of $N(N - 1)/2 = 91$ log real per-capita output differentials.

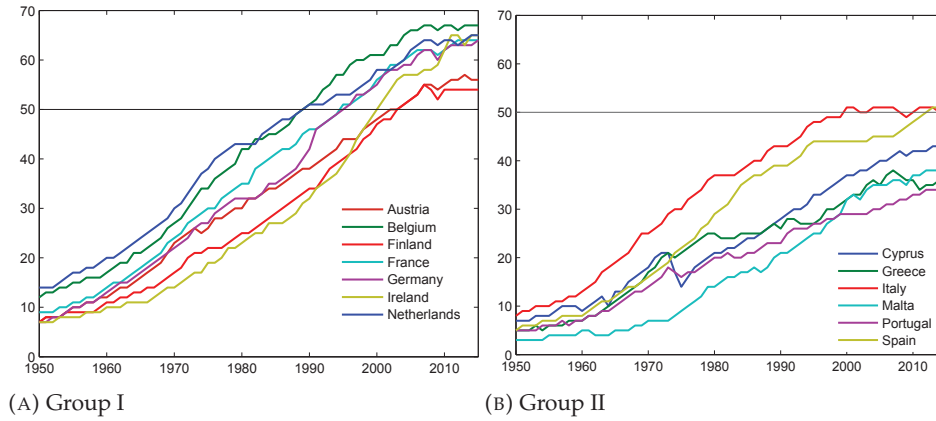


FIGURE 5: Output per hour worked in 2014 US\$

Note: Data is converted to 2014 price level with updated 2011 PPPs. Source: The Conference Board Total Economy Database™

We start by analysing the nonstationarity properties of output disparities using conventional unit root tests, and complement this analysis with persistence change tests (which are briefly described in the Appendix) to draw more robust conclusions about the stationarity or nonstationarity of countries output differentials. The rejection of the null hypothesis of nonstationarity, $I(1)$, or its rejection in favor of a change from nonstationarity to stationarity, *i.e.* $I(1)-I(0)$, can be indicative of convergence.

Table 1 summarises the results and presents information of which countries' pairs report persistent convergence/divergence paths over the sample period, and which of them exhibit changes of the convergence path. We should attend to the fact that 15% of the observations at the beginning and at the end of the sample period are excluded by the persistence change tests. Therefore, in practice, the results report to the period from 1960 to 2006. The first column of Table 1 refers to the reference country considered and the following four columns indicate the conclusion of the tests computed on the output differential with the countries listed in that column. For instance, considering the first line of Table 1, we observe that the output differentials of Austria (the reference country) with, for instance, Ireland is stationary ($I(0)$), whereas with Italy, the Netherlands, Portugal and Spain are nonstationary ($I(1)$). For the remaining countries considered, we observe that the output differentials of Austria with Belgium, Finland, France, Germany and Luxembourg show persistence change from nonstationarity ($I(1)$) to stationarity ($I(0)$), whereas the output differentials of Austria with Cyprus, Greece and Malta also display persistence change, but in this case from stationarity ($I(0)$) to nonstationarity ($I(1)$).

In general, results provide evidence of stationary (or changes to stationary) output differences in around 72% of the cases in Group I, 47% of cases in Group II, and in around 43% of cases overall. No persistence change was found in 8 series, representing 8.8% of total. The no persistence change hypothesis was rejected for 83 series. Evidence of $I(0) - I(1)$ changes was detected in 46 series, representing 50.5% of all series, which corresponds to cases of economic divergence. Evidence of $I(1) - I(0)$ changes is present in 37 series, or 40.7% of total. Therefore, the results suggest that 39 (two of the series for which no persistence change was found are stationary) out of 91 series represent potential cases of convergence while 52 series represent situations of economic divergence between countries.

The results suggest that there has been a persistence change from stationarity to nonstationarity in most countries of Group II relatively to most countries of Group I. In fact, there is evidence that Portugal, Malta, Cyprus, Spain and Greece started a process of reduction of output differentials with all, or almost all of the countries in Group I. In particular, Greece and Cyprus report evidence of changes from $I(0)$ to $I(1)$ with all countries in Group I; Portugal and Spain report such changes relatively to five countries in Group I. Results also suggest evidence that the output differentials of these countries relatively to some other countries in Group I are unstable over the sample period. Malta reports changes for $I(0)$ to $I(1)$, corresponding to unstable output differentials, relatively to four countries, while the output differentials between Italy and three other countries seem to be $I(1)$. From this perspective, results seem to suggest that there is heterogeneity in the evolution of the output differentials between the two groups of countries.

The intra-groups analysis also reveals interesting results. For instance, Ireland seems to be the only divergent country inside Group I. The other countries report a change to convergence in the period. This suggests that these countries managed to reduce their output differentials and consolidated the proximity of their income levels. The countries in Group II report mixed evidence with several output differentials reporting unstable paths. The most remarkable result concerns to Greece which reports a change from $I(0)$ to $I(1)$ in the output differentials with almost all countries. The other countries, such as Portugal, Italy, Malta and Spain report a change to stable output differentials relatively to three countries and Cyprus seems to have enacted convergence with two countries.

Table 1: Persistence of European Output Differentials (1950–2014)

	I(0)	I(1) to I(0)	I(0) to I(1)	I(1)
Austria	Ireland	Belgium, Finland, France, Germany, Luxembourg	Cyprus, Greece, Malta	Italy, Netherlands Portugal, Spain
Belgium	—	Austria, France, Germany, Malta, Netherlands, Luxembourg, Italy	Cyprus, Finland, Greece, Ireland, Portugal, Spain	—
Finland	—	Germany, Spain, Luxembourg Austria, France, Netherlands, Italy	Belgium, Portugal, Cyprus, Ireland, Greece, Malta	—
France	—	Austria, Belgium, Malta, Finland, Netherlands, Germany, Italy, Luxembourg	Ireland, Portugal, Cyprus, Greece, Spain	—
Germany	Netherlands	Austria, Malta, Belgium Finland, France, Luxembourg	Cyprus, Greece, Ireland, Italy, Spain	Portugal
Ireland	Austria	—	Belgium, Italy, Luxembourg, Finland, Cyprus, Greece, Germany, France, Malta, Netherlands, Portugal, Spain	—
Netherlands	Germany	Belgium, Finland, France, Italy, Luxembourg	Cyprus, Greece, Ireland, Malta, Portugal, Spain	Austria
Luxembourg	—	Austria, Belgium, Finland, France, Malta, Portugal, Spain, Germany, Netherlands, Italy	Ireland, Greece, Cyprus	—

Table 1: Persistence of European Output Differentials (1950–2014) - Cont.

	I(0)	I(1) to I(0)	I(0) to I(1)	I(1)
Cyprus	—	Italy, Spain	Austria, Belgium, France, Finland, Germany, Ireland, Greece, Malta, Luxembourg, Netherlands, Portugal	—
Greece	—	—	Austria, Belgium, Finland, Italy, France, Malta, Netherlands, Portugal, Cyprus, Germany, Ireland, Luxembourg	Spain
Italy	—	Belgium, Cyprus, Malta, Netherlands Finland, France, Luxembourg, Portugal	Germany, Spain, Ireland, Greece	Austria
Malta	—	Belgium, Italy, Portugal France, Germany, Spain, Luxembourg	Austria, Finland, Cyprus, Ireland, Netherlands	Greece
Portugal	—	Spain, Luxembourg, Italy, Malta	Belgium, Finland, France, Ireland Greece, Cyprus, Netherlands	Austria, Germany
Spain	—	Luxembourg, Finland, Cyprus, Portugal, Malta	Belgium, France, Germany, Ireland Italy, Netherlands	Austria, Greece

Source: Authors' calculation.

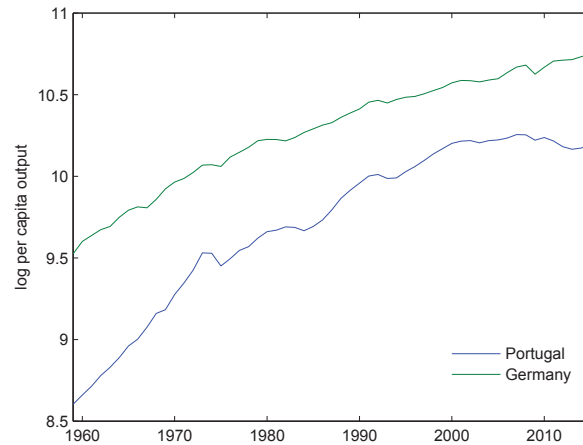


FIGURE 6: Log of per capita output in Germany and Portugal.

Source: The Conference Board Total Economy Database™.

Hence, according to equation (2) the possible countries that have converged with the reference countries considered are the ones which are listed in the stationarity column ($I(0)$) and those that observed persistence change from nonstationarity ($I(1)$) to stationarity ($I(0)$). Note that the conclusions for the countries in the other two columns do not necessarily mean that these countries are diverging. In effect, many of these countries went (and are still going) through a catching up process, which means that their log per capita outputs show dynamic profiles which differ from that of the reference country considered.

As an example consider for instance the evolution of the log per capita output in Portugal and Germany between 1960 and 2015 in Figure 5. Although the test tells us that the output differential between these two countries is nonstationary ($I(1)$), hence the steady state behaviour of the two countries has still significant differences, this nonstationarity is clearly a reflection of the catching up growth path followed by Portugal.

Therefore, from equation (2) and the definition of convergence considered, to conclude for convergence the deterministic trend also needs to be statistically insignificant. After establishing stationarity in the previous analysis we observe that the only pairs of countries for which the time trend is not significant are (countries in bold letters in Table 1): Austria - Ireland, Austria - Belgium, Austria - Finland, Belgium - Netherlands, Belgium - Italy, Finland - Netherlands, Finland - Spain, Finland - Italy, France - Malta, France - Germany, Germany - Malta, Luxembourg - Malta, Luxembourg - Italy, Cyprus - Italy, Cyprus - Spain, Malta - Portugal, Malta - Spain and Portugal - Spain. For these pairs, the test suggests that there has been convergence

over the sample period, or that there has been a change from divergence to convergence. For illustration purpose on this point, consider Figure 6 which exhibits the evolution of per capita output in log levels of Portugal and Spain, on the one hand, and Luxembourg and Malta on the other, for which we gathered evidence of convergence.

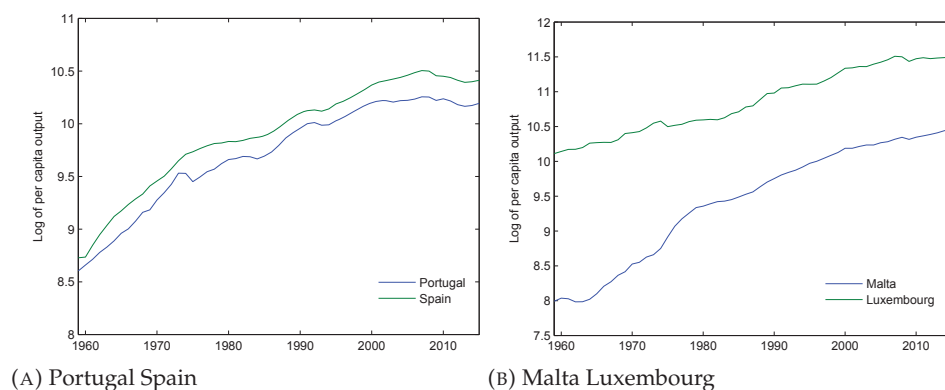


FIGURE 7: Log of per capita output in Portugal, Spain, Luxembourg and Malta.

Source: The Conference Board Total Economy Database™.

A further important piece of information that we can draw from equation (2) relates to the intercept term, which, according to this model, measures differentials in the countries' initial conditions; see Table 2.

Table 2: Intercept estimates from (2)

Country pairs	$\hat{\delta}$	
Belgium - Austria	0.0078	
Finland - Austria	-0.0299	***
Ireland - Austria	0.0026	
Italy - Belgium	0.0137	
Netherlands - Belgium	0.0299	***
Italy - Cyprus	0.1143	
Spain - Cyprus	0.0531	*
Italy - Finland	0.0252	
Netherlands - Finland	0.0616	**
Germany - France	0.0097	**
Malta - France	0.0035	
Malta - Germany	0.0036	
Luxembourg - Italy	-0.0978	
Netherlands - Italy	-0.0094	
Malta - Luxembourg	0.0972	
Portugal - Malta	0.0074	
Spain - Malta	-0.0010	
Spain - Portugal	0.0567	***

Note: ***, **, * denote significance at 1%, 5% and 10%, respectively.

The statistical significance of the estimates of δ_{ij} , of the parameter that depends on the initial conditions in countries i and j in (2), indicates that these conditions are relevant in the pairs: Finland - Austria, Netherlands - Belgium, Netherlands - Finland, Germany - France and Spain - Portugal. In all these cases, a change from I(1) to I(0) was found.

Note that the sign of the intercept depends on the ordering of the countries considered, for instance, a negative (positive) sign indicates that the initial conditions in the reference country are larger (smaller) than in the country with which it is compared with. For example, the significant value of -0.0299 observed for Finland - Austria suggest that the initial conditions in Austria were more favourable than in Finland.

Conclusions

The results suggest that over the period under analysis, many log per capita output differentials are still not stable, particularly between Group I and Group II members and within Group II. In fact, Cyprus, Greece, Malta, Italy, Portugal and Spain, display unstable differentials relatively to countries in Group I, which in general may be indicative of the catching up process these countries are pursuing. Greece also displays unstable differentials relatively to

countries in group I, while Ireland has been on a diverging trajectory vis-à-vis almost all countries.

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Appendix A: Group Convergence

An alternative way to show the different dynamics of the countries, in line with the β -convergence concept, is to plot the average growth rate over a period of time (e.g. 1960 - 1980) against the initial level (1960) of real output per worker. A negative relationship between the initial level of output per worker and its average growth rate means that lesser developed countries tend to grow faster than developed ones and will eventually catch up with them. In graph A) of Figure A.1 we observe this phenomena, i.e. a convergence trend within the group of countries, and diversity of growth rates across countries. Although the period between 1960 and 1980 seems to provide some support to the idea that countries are converging to a common level of income, since a downward sloping relationship between growth and the initial income can be observed, this evidence seems to decrease after 1980. It is also observed that after 1980 the growth rates declined and became substantially lower particularly between 2000 and 2014.

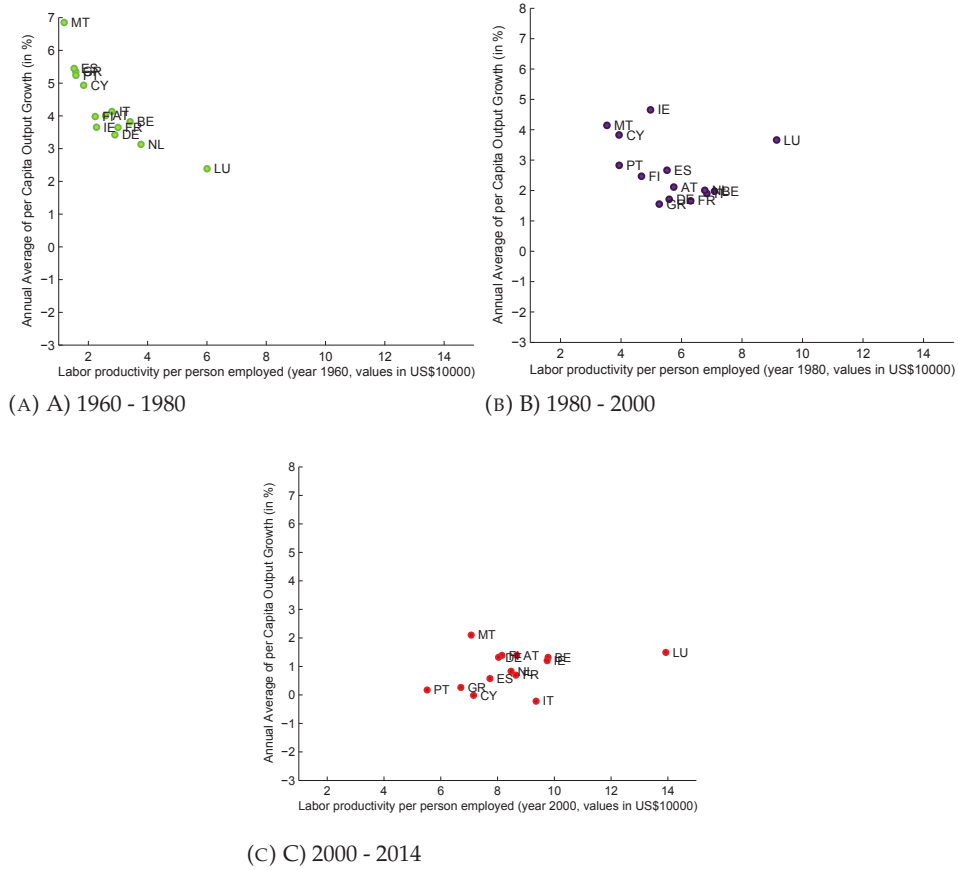


FIGURE A.1: Output growth vs labor productivity (1960, 1980, 2000)

Source: The Conference Board Total Economy DatabaseTM and Author's calculations

To further corroborate these results, Figure A.2 looks at σ -convergence, which analyses convergence from a different angle. In particular, it evaluates whether the overall dispersion of per capita output or within the groups is increasing (divergence) or decreasing (convergence). From Figure A.2 we observe that until around 2008-2009, this indicator was decreasing, suggesting that lesser developed countries were catching up with developed countries. However, from 2009 onwards the dispersion seems to start to increase, mainly as a consequence of the divergence observed in the countries of Group II. Note that the progress of σ -convergence is not only a function of the differential rates of growth between lesser developed and developed countries, but also of the size of the initial output differential.

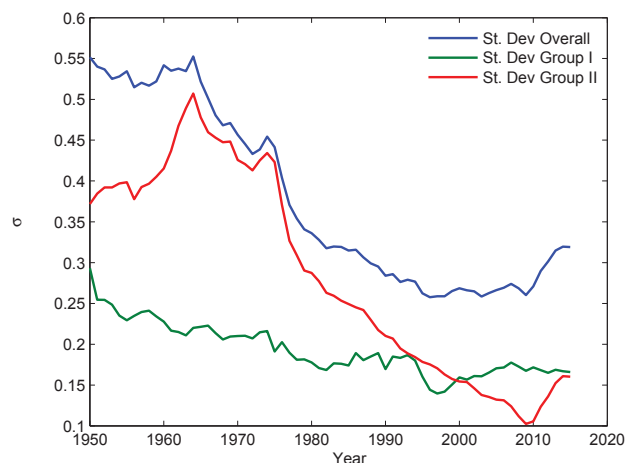


FIGURE A.2: Sigma-Convergence.

Source: The Conference Board Total Economy Database™ and Authors' calculations.

Appendix B: Appendix - Tests for persistence of output convergence

Testing for the persistence of macroeconomic time series, allowing for the classification of series as stationary or nonstationary is meaningful for the purposes of this paper in that it helps understand the position of each country in its catching-up process relatively to others and the effect of shocks on output differentials.

B.1. The persistence change model

For the purpose of presenting the persistence change tests, we follow Harvey et al. (2006) and Buseti and Taylor (2004) and consider the following data generation process,

$$\begin{aligned} y_t &= \mathbf{z}_t' \beta + x_t \\ x_t &= \rho_t x_{t-1} + \varepsilon_t \end{aligned}$$

with $x_0 = 0$. In our particular context \mathbf{z}_t is a set of deterministic variables, such as a constant or a time trend (if necessary). The $\{x_t\}$ is assumed to satisfy the mild regularity conditions of Phillips and Xiao (1998) and the innovation sequence $\{\varepsilon_t\}$ is assumed to be a mean zero process satisfying the familiar α -mixing conditions of Phillips and Perron (1988, p.336) with strictly positive

and bounded long-run variance, $\omega^2 \equiv \lim_{T \rightarrow \infty} E \left(\sum_{t=1}^T \varepsilon_t \right)^2$; see Harvey et al. (2006, p. 444) for details.

Four relevant hypothesis can be considered:

1. $H_1 : y_t$ is $I(1)$ (i.e. nonstationary) throughout the sample period. Harvey et al. (2006) set $\rho_t = 1 - c/T$, $c \geq 0$, so as to allow for unit root and near unit root behaviour.
2. $H_{01} : y_t$ is $I(0)$ changing to $I(1)$ (in other words, stationary changing to nonstationary) at time $[\tau^*T]$; that is $\rho_t = \rho$, $\rho < 1$ for $t \leq [\tau^*T]$ and $\rho_t = 1 - c/T$ for $t > [\tau^*T]$. The change point proportion, τ^* , is assumed to be an unknown point in $\Lambda = [\tau_l, \tau_u]$, an interval in $(0,1)$ which is symmetric around 0.5;
3. $H_{10} : y_t$ is $I(1)$ changing to $I(0)$ (i.e. nonstationary changing to stationary) at time $[\tau^*T]$;
4. $H_0 : y_t$ is $I(0)$ (stationary) throughout the sample period.

B.2. The persistence change ratio-based tests

In the context of no breaks, Kim (2000), Kim et al. (2002) and Buseti and Taylor (2004) develop tests for the constant $I(0)$ DGP (H_0) against the $I(0) - I(1)$ change (H_{01}) which are based on the ratio statistic,

$$K_{[\tau T]} = \frac{(T - [\tau T])^{-2} \sum_{t=[\tau T]+1}^T \left(\sum_{i=[\tau T]+1}^t \tilde{v}_{i\tau} \right)^2}{[\tau T]^{-2} \sum_{t=1}^{[\tau T]} \left(\sum_{i=1}^t \hat{v}_{i\tau} \right)^2}$$

where $\hat{v}_{i\tau}$ is the residual from the OLS regression of y_t on x_t for observations up to $[\tau T]$ and $\tilde{v}_{i\tau}$ is the OLS residual from the regression of y_t on x_t for $t = [\tau T] + 1, \dots, T$.

Since the true change point, τ^* , is assumed unknown Kim (2000), Kim et al. (2002) and Buseti and Taylor (2004) consider three statistics based on the sequence of statistics $\{K(\tau), \tau \in \Lambda\}$, where $\Lambda = [\tau_l, \tau_u]$ is a compact subset of

$[0,1]$, *i.e.*,

$$K_1 = T_*^{-1} \sum_{s=[\tau_l]}^{[\tau_u]} K(s/T); \quad (\text{B.1})$$

$$K_2 = \ln \left\{ T_*^{-1} \sum_{s=[\tau_l]}^{[\tau_u]} \exp \left[\frac{1}{2} K(s/T) \right] \right\}; \quad (\text{B.2})$$

$$K_3 = \max_{s \in \{[\tau_l], \dots, [\tau_u]\}} K(s/T) \quad (\text{B.3})$$

where $T_* = [\tau_u] - [\tau_l] + 1$, and τ_l and τ_u correspond to the (arbitrary) lower and upper values of τ^* . Limit results and critical values for the statistics in (B.1) - (B.3) can be found in Harvey et al. (2006).

Note that the procedure in (B.1) corresponds to the mean score approach of Hansen (1991), (B.2) is the mean exponential approach of Andrews and Ploberger (1994) and finally (B.3) is the maximum Chow approach of Davies (1977); see also Andrews (1993).

In order to test H_0 against the $I(1)$ - $I(0)$ (H_{10}) hypothesis, Busetti and Taylor (2004) propose further tests based on the sequence of reciprocals of K_t , $t = [\tau_l], \dots, [\tau_u]$. They define K_1^R, K_2^R and K_3^R as the respective analogues of K_1, K_2 and K_3 , with $K_j, j = 1, 2, 3$ replaced by K_j^{-1} throughout. Furthermore, to test against an unknown direction of change (that is either a change from $I(0)$ to $I(1)$ or vice versa), they propose $K_i^M = \max [K_i, K_i^R], i = 1, 2, 3$. Thus, tests which reject for large values of $K_i, i = 1, 2, 3$ can be used to detect H_{01} , tests which reject for large values of $K_i^R, i = 1, 2, 3$ can be used to detect H_{10} and $K_i^M, i = 1, 2, 3$ can be used to detect either H_{01} or H_{10} .

