Essays on Currency Internationalization and Exchange Rate Regime Choice – Empirical Evidence from Asia and Europe

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Abstract

This dissertation is a collection of three essays on the internationalization of currencies and the choice of exchange rate regimes, focusing on the Chinese renminbi (RMB) and the euro. It adds to the literature with empirical results, institutional analyses, and methodological elaborations.

The first part of the study, we investigate the evolution of offshore RMB trading between 2016 and 2019. We find some convergence with the geographical distribution pattern of major currencies in international financial markets, but it is strongly influenced by (geopolitical) disputes and trading intensity. In addition, during the period under consideration, policy measures and the characteristics of financial centers played a role in shaping the offshore RMB trading pattern. The analysis is also conducted for the euro and reveals evidence for convergence in the first years after its introduction. The determinants of euro trading are not stable over time but include links between the eurozone and offshore trading centers and the economic and institutional characteristics of these centers.

The second part incorporates two essays on exchange rate regime choice. A key policy criterion identified in the literature to evaluate optimal currency areas is the co-movement of business cycle shocks. However, we show that a currency area is optimal and a common monetary policy is suitable for all members only if, in addition, there is also a common impulse response pattern over time. The serial correlation common features test is the appropriate testing procedure for this, and we provide a theoretical underpinning for empirical studies that have used this test to evaluate common currency areas. In our empirical analysis, we account for seasonality in GDP data and jointly model common cycles and common seasonal factors. First, we consider countries potentially acceding to the European Monetary Union and find no evidence for a common cyclical reaction pattern with the euro area aggregate, except for Sweden. Second, we contribute to the literature discussing various types of new currency arrangements around the RMB, up to and including fixed exchange rates in an RMB currency bloc. The background is that the RMB increasingly challenges the dominant role of the U.S. dollar in the East Asian region, and relations with China are becoming closer. Despite these conditions, the results do not reveal common synchronous cycles, but show few common cyclical elements for Korea, Hong Kong, and Taiwan, which is in contrast to previous studies.

Keywords: FX turnover; Geographical trading pattern; Renminbi internationalization; Dispute; Trade intensity; Codependent business cycles; Serial correlation common feature; European monetary integration; Seasonality; Optimum currency area; Exchange rate regime choice.

JEL Classifications: C24, F31, F33, G15, G18, C32, E32, F36, E52, F41.

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List of Abbreviations

2SLS .... *Two stage least squares*
AIC .... *Akaike Information Criterion*
AR .... *Autoregressive*
AREAER .... *Annual Report on Exchange Rate Arrangements and Exchange Restrictions*
ASEAN+3 .... *Association of Southeast Asian Nations Plus Three*
BIS .... *Bank for International Settlements*
CEE .... *Central and Eastern European*
CFETS .... *China Foreign Exchange Trade System*
CMI .... *Chiang Mai Initiative*
DOTS .... *Direction of Trade Statistics*
EA12 .... *Euro area 12 (initial 12 countries)*
EAEC .... *European Atomic Energy Community*
EC .... *European Community*
ECB .... *European Central Bank*
ECSC .... *European Coal and Steel Community*
EDP .... *EXcessive Deficit Procedure*
EEC .... *European Economic Community*
EMU .... *Economic and Monetary Union*
ERM .... *Exchange Rate Mechanism*
EU .... *European Union*
FTA .... *Free Trade Agreement*
FX .... *Foreign exchange*
GDP .... *Gross domestic product*
GMM .... *Generalized method of moments*
HICP .... *Harmonized consumer price inflation*
IFS .... *International Financial Statistics (IMF)*
IMF .... *International Monetary Fund*
OCA .... *Optimum currency area*
RMB .... *Renminbi*
RQFII .... *Renminbi qualified foreign institutional investor*
SCCF .... *Serial correlation common features*
SDR .... *Special Drawing Rights*
SIC .... *Schwarz Information Criterion*

SWIFT .... *Society for Worldwide Interbank Financial Telecommunication*
TFEU .... *Treaty on the Functioning of the European Union*
THAAD .... *Terminal High Altitutde Area Defense*
U.S. .... *United States*
VAR .... *Vector autoregressive*

Introduction

The foreign exchange (FX) market is the largest financial market globally. Since the liberalization of financial markets after the abandonment of the Bretton Woods system, the average daily turnover in the FX market has risen sharply, and the daily turnover far exceeds the payment transactions needed to settle trade and direct investment flows. The Bank for International Settlements (BIS) has conducted a study of the average daily turnover every three years since 1986. The most recent study, conducted in April 2022, shows that trades worth an average of 7,505,992 million USD were executed daily on global trading venues. The United States (U.S.) dollar accounted for the largest share of these trades (88%), followed by the euro (30%), Japanese yen (17%), British pound (13%), and Chinese RMB (7%).[1] The performance of the RMB is particularly noteworthy, as it was ranked eighth three years earlier in 2019. However, the majority of turnover is concentrated in a few trading venues; the top five account for 78% turnover: the United Kingdom (38%), the United States (19%), Singapore (9%), Hong Kong (7%), and Japan (4%).

The FX market is, of course, also subject to geopolitical influences. The growth rate of 14% between 2019 and 2022 is one of the lowest since BIS began monitoring it. Geopolitical tensions following the Russian invasion of Ukraine and COVID-19 restrictions may also have suppressed turnover. However, even before 2019, there were tensions due to international conflicts, such as the trade disputes between China and the U.S. and other countries, which were followed by sanctions.

Against this background, analyzing the geographic distribution pattern of individual currencies is insightful. The offshore trading of the RMB and the euro are examined, both however before the COVID-19 pandemic. China's policy of internationalizing the RMB provides an opportunity to assess the impact of various targeted policies.

[1] Since two currencies are involved in each transaction, the total is 200%.

In addition to the great importance of the FX markets themselves, the exchange rates generated in them also impact the real economy. According to the International Monetary Fund (2021), about 33% of the world's currencies have flexible exchange rates, while 13% have hard pegs. In between these two systems, there exist a variety of more or less fixed regimes. Fixed exchange rates lead to a reduction in transaction costs and uncertainty by eliminating exchange rate risk. This can promote trade, which is, for example, one of the European Union's (EU) central tasks regarding the single market.

However, fixed exchange rates or even a common currency also cause constraints, as the exchange rate can no longer fulfill its balancing shock-absorbing function. Thus, with fixed exchange rates, shocks must be absorbed by other mechanisms, and a deeper integration is beneficial, including labor and capital flexibility. In most cases, however, these mechanisms cannot fully absorb the effects of asymmetric shocks. In addition, a common central bank can respond to shocks only in one way, which is not necessarily optimal for each country since countries still have different external trade linkages and different tolerances of unemployment and inflation. Therefore, it is important to examine the suitability of individual countries to form or enter a monetary union.

Currency unions are currently discussed not only in the economic literature but also in the public media. Croatia, for example, met the convergence criteria and fulfilled its obligation to introduce the euro at the beginning of this year. Other countries, some of which joined the EU before Croatia did, have not yet introduced the euro and are pursuing to do so with differing levels of effort. Furthermore, Brazilian President Luiz Inácio Lula da Silva and Argentine leader Alberto Fernandez announced plans to advance discussions on a common South American currency, el sur, earlier this year. They also stated that they wanted to reduce their dependence on the United States. In the ensuing discussions, economists tended to emphasize the differences between the countries and were critical of the introduction of a common currency. Moreover, many fixed exchange rate systems that existed between Asian countries and the United States were dissolved, and discussions about alternative anchor currencies arose. Nevertheless, a common currency requires close cooperation between the countries involved in terms of economic and financial policy, which is developing in Asia but is not well established yet. At this point, we contribute to the literature by examining optimal currency areas in Europe and Asia and by providing a theoretical underpinning to a well-established testing procedure.

Summary

This dissertation is a collection of three essays, the first of which addresses the internationalization of currencies, in particular the RMB and the euro. The other two essays discuss the choice of optimal exchange rate regimes and provide an empirical analysis for Europe and Asia.

Part 1 of this thesis is on currency internationalization.[2] There are only a few major currencies globally and the U.S. dollar still dominates international financial markets. However, two different currencies challenge its dominant position: the euro and the Chinese RMB. The euro superseded 11 existing currencies with its introduction and was thus directly represented on international financial markets in a large number of countries. Under the Treaty on the Functioning of the European Union (TFEU), all members are required to adopt the euro. However, a prerequisite is the fulfillment of several convergence criteria. The RMB, on the other hand, was introduced in the People's Republic of China in 1949. Although it is still not fully convertible, since 2009, China has taken more and more measures to increase its convertibility and international use.

Section 1.2 provides an overview of the internationalization process of the RMB. First, it highlights various policy measures to promote the international role of the renminbi. These measures include local RMB clearing banks, the setup of bilateral RMB currency swap agreements, and the assignment of investment quotas. For example, the RMB is the fifth most actively traded currency, according to Worldwide Interbank Financial Telecommunication (SWIFT). However, in terms of proportionate average daily turnover share, reported in the 2019 BIS Triennial Survey, the RMB ranks seventh. The intrusion of the RMB in international financial markets has changed significantly over the past 20 years, and the RMB has gone from being a minor currency to one of the most important. Cheung et al. (2019) hypothesized that the RMB would converge to a

[2] Parts of this section are based on joint work with Yin-Wong Cheung and Frank Westermann and have already been published (see Cheung et al., 2021).

similar geographic distribution pattern as other major currencies. The following section empirically tests this hypothesis for the period 2016 – 2019.

To investigate whether the renminbi converges to a global distribution pattern, we construct a regression equation in which the change in the share of RMB trading of each trading center, as reported in the BIS Triennial Surveys from 2016 and 2019, is explained by two groups of variables: (a) variables that contain FX market information and (b) variables that reflect geopolitical conditions. One the one hand, FX market variables include the change in the share of global FX trading and the share of RMB trading in total trading in the respective jurisdiction. Convergence is captured by a gap variable, which serves as an error correction term. The gap between the jurisdiction i's share of offshore RMB trading and its share of global FX trading is considered. If the share of RMB trading in the respective center is lower than its share of total FX trading, RMB trading in that center is assumed to increase. On the other hand, the second group of variables, geopolitical variables, includes trade intensity and a dummy variable for countries in a dispute with China. It is important to take these circumstances into account, as they play an important role in the geopolitical environment in the considered period between 2016 and 2019.

The results of this basic specification reveal evidence of a convergence of RMB trading to a geographic pattern of major international currencies, after accounting for trade and dispute variables. Since Hong Kong plays a special role in RMB offshore trading and most of the offshore RMB is traded in Hong Kong, additionally, the regression is estimated without this trading center. The results, however, remain robust, and the outcome is not driven by this trading center.

In the following section, we add three additional groups of explanatory variables to the basic regression to investigate further possible determinants of RMB expansion. The three sets of variables include information on (a) policies adopted by China to promote internationalization, (b) linkages that exist between the respective countries and China, and (c) characteristics of these trading centers. The results reveal that China's policies and jurisdictions' characteristics influence the change in the share of RMB trade, but links to China do not. Finally, the development of the RMB is contextualized with respect to the other currencies included in the Special Drawing Rights (SDR) basket. Since these currencies completed most of their development long ago, we do not expect a convergence process. In fact, primarily, the change in the share of total FX trading explains the change in the jurisdiction's share in RMB trading for the U.S. dollar and Japanese yen, the euro and the British pound. However, for the latter, an additional convergence process seems to occur during this period. Since the geopolitical situation cannot be simply transferred (the countries related to these currencies do not have tensions with the same countries as China), the estimation equation contains only FX-market-related variables. The development of the euro is discussed in more detail in the following section.

Since the euro was introduced in 1999 the development of the euro trade can be observed from the beginning using BIS data, which has been available since 1986. As for the other SDR currencies in the previous section, the basic regression contains only FX market related variables. Under this specification, a convergence process can be observed in the first years after the euro's introduction. Subsequently, other possible determinants are also examined: links between the offshore centers and the euro area, economic characteristics of the jurisdictions, and institutional characteristics of these. Over time, information from all three groups have an effect, but this is not stable over time.

Section 1.5 summarizes the results from the first part of this thesis and concludes that the development of the RMB into a major international currency is unique. It differs from the euro in that China can influence the international use of the RMB through policy measures, as this currency still has a relatively small market share and has not reached its potential value yet. The euro also experienced a convergence process initially, but it built on previously existing currencies. Neither the RMB nor the euro has reached the U.S. dollar, however.

The second part of this thesis addresses the choice of the optimal exchange rate regime. This topic is repeatedly the focus of economic and political discussions. Triggering moments for this were, for example, the gold standard and its failure, the considerations on the formation of a European Monetary Union, the introduction of the euro and, finally, the subsequent accessions to the EU and the currency area. Various possible exchange rate regimes around the Chinese RMB have been discussed in the literature as a consequence of China's development into one of the world's largest economies, its increasing influence in almost all economic and political areas, and the simultaneous detachment of East and Southeast Asian economies from the U.S. dollar. Discussions range up to the concept of an RMB currency bloc.[3]

This part of the paper will first provide an insight into the theory of optimal currency areas (OCA), as that constitutes the background for the following considerations and discussions. Building on the seminal paper by Robert Mundell (1961), researchers have developed various criteria to help assess whether countries should form an optimal currency area or adopt a common currency and to weigh the advantages and disadvantages of a common currency. These criteria include factor mobility, diversification in production, financial and policy integration, and intensity of trade. An implicit criterion is the symmetry of shocks and synchronization of business cycles. The idea behind this criterion is that a common central bank can respond to symmetric shocks with its monetary policy in a relatively suitable way for all member countries of the monetary union. The suitability of the (common) monetary policy is particularly relevant in the case of a lack of alternative adjustment mechanisms, such as a lack of labor mobility or imperfect wage-price flexibility. We argue that contemporarily correlated shocks can have asymmetric effects – thus, not only is the correlation of shocks a key OCA criterion, but the common persistence of shocks or a common impulse response pattern across countries is also equally important. To test this, the serial correlations common features (SCCF) test is used in the literature. In the following section, we provide a theoretical underpinning for the use of this test in the context of optimal currency areas.

In Section 2.3, we set up a model in the Barro-Gordon (1983) framework and extend the model on optimal exchange rate regime choice by Berger et al. (2001), highlighting the effects of autocorrelated shocks. We first present the case of flexible

[3] Parts of this section are based on joint work with Sven Steinkamp and Frank Westermann, which includes the conceptual framework, the transition to the empirical test, and the empirical analysis of the eurozone accession candidates (see Grimm et al., 2021). I have extended these by including an institutional analysis and the analysis of eurozone members. The analysis of East Asian countries and China is an extended version of Grimm (2022).

exchange rates. Here, we find that the persistence of shocks affects the inflation bias and that shock persistence under flexible exchange rates does not affect the expected welfare loss. We show that if, for example, a small country then joins a monetary union – that is, a fixed exchange rate regime is introduced – there are additional welfare losses in the case of asymmetric shock persistence and that a symmetric equilibrium arises only in the case of identical persistence of shocks.

The empirical implication from the conceptual framework is that the persistence of shocks in two countries forming a monetary union should be identical. When the conceptual framework is applied to higher-order autocorrelated processes, it becomes apparent that not only the persistence parameters of the autoregressive (AR) term of order one, AR(1), but all coefficients in the AR(p) process must be identical. For this purpose, the SCCF test can be used. It tests for a higher-order common AR(p) process in different time series by identifying the existence of a linear combination of two variables that is free of autocorrelation. An alternative interpretation of SCCF is that the impulse response patterns of two variables must be identical when they face a common exogenous shock. Since the test for common features was first proposed by Engle and Kozicki (1993) and Vahid and Engle (1993, 1997), there have been many applications and further developments of the test procedure. We follow Cubadda (1999), who proposed an integrated approach that incorporates common serial correlations, common trends, and seasonality into the testing procedure since the use of de-seasonalized data can lead to the detection of spurious common cycles. In the following sections, we apply this test to acceding countries to the euro area as well as to 10 East Asian countries and China. The test is preceded by an institutional analysis and some preliminary analyses.

First, the potentially acceding countries to the euro area are analyzed. Before the implicit OCA criterion is examined, the degree to which the acceding countries satisfy formal criteria is shown. According to the Treaty on the Functioning of the European Union, EU members are obliged to adopt the euro. However, this means that these countries are required to meet convergence criteria. The criteria are price stability, sound and sustainable public finances, exchange rate stability, and durability of convergence. In addition, national laws and rules must fit the treaty's provisions, including, for example, the independence of the central bank. The European Commission regularly checks whether the accession candidates meet the criteria. In 2022, it determined that, except Croatia, none of the acceding countries met all the convergence criteria. In addition to these formal criteria, the willingness of the population of the countries to adopt the euro is also presented briefly in this section. The willingness of the population does not always coincide with the government's attitude. Overall, the populations of the Czech Republic, Bulgaria and Sweden are against the introduction of the euro.

Section 2.5.2 briefly presents other studies that, with a focus on business cycles or correlation of shocks, examine the now euro countries or the acceding countries. Overall, there is mixed evidence for symmetric shocks and common business cycles. Often, results are found that suggest the division of countries into a core group and peripheral countries.

Our empirical examination starts with some preliminary analysis. First, the seasonal growth rates of real logged gross domestic product (GDP) from 1999Q1 to 2019Q3[4] are displayed graphically. The estimation of correlation coefficients confirms the apparent picture of a strong correlation between the growth rates of the individual countries' GDP and that of the euro area aggregate. For an impression of the persistence of shocks and the cyclical response pattern of the individual countries to an exogenous shock, the autocorrelation functions of the individual acceding countries are presented in comparison to the autocorrelation function of the euro area aggregate. The correlograms of the acceding countries, except for Poland and Sweden, are quite different from that of the aggregate. In addition, we perform a seasonal unit root test, following Hylleberg et al. (1990), and a seasonal cointegration test. These tests are not the focus of the analysis, but the resulting characteristics are considered in the subsequent SCCF test. In a bivariate setting, we perform both the common features test, which tests for identical impulse response patterns and follows from our conceptual framework, and the less strict test for codependence, in which the initial response may differ. We find evidence for identical impulse response patterns only for Sweden. However, the Czech Republic and Croatia also display some similarity in the sense of a common, but not perfectly synchronized

[4] As Croatia has adopted the euro in 2023, it is classified as a candidate country in our analysis.

common cycle with the euro area aggregate. When considering higher orders of codependence up to three, we find common cyclical features for all countries. We investigate the robustness of this result by examining the sensitivity to the lag selection and applying an alternative version of the codependency test based on canonical correlations. Using these tests, we are able to confirm most of our results. However, at a higher lag order, there is also evidence of a common impulse response pattern for the Czech Republic, and the canonical correlation-based test does not confirm perfectly synchronized cycles with the euro area aggregate for Sweden.

Following the analysis of acceding countries to the euro area, the next section examines the current members of the monetary union. Again, there is a high degree of correlation between the euro area aggregate (minus the country in question). A visual inspection of autocorrelograms shows a high degree of similarity for all countries except Spain, Greece, and Ireland. The formal test for common reactions to shocks reveals impulse response patterns identical to those of the aggregate for only six out of the 12 countries under consideration. For almost all of them, however, there are no perfect synchronized cycles. Overall, nevertheless, there is significantly more evidence of common reactions to shocks for the euro area countries than for the candidate countries.

The next section, Section 2.6, considers the closer monetary cooperation of East and Southeast Asian[5] countries with China proposed in the literature. This section begins with an institutional background that supports the idea of closer monetary cooperation. The background includes, on the one hand, closer ties among East Asian countries and with China and, on the other hand, weakening ties with the U.S. and the U.S. dollar, which had previously been quite influential in this region. Thus, as a result of the Asian crisis in 1997/8, many fixed exchange rate systems that existed between East Asian currencies and the U.S. dollar were dissoluted. In addition, several initiatives were established to promote integration within the region. Moreover, not only is there more bilateral trade between these countries and China than with the U.S., but their volume of bilateral trade with China has also increased sharply. While the role of the Chinese RMB

[5] Even though I have included East Asian countries and Southeast Asian countries in my studies, for brevity I will frequently group them under East Asia.

in international financial markets is increasing, not least due to measures taken by the Chinese government to promote the internationalization of the RMB, the U.S. dollar remains the dominant currency.

Two studies in the previous literature are particularly relevant for the empirical analysis that follows in this study, as they also examined Asian countries in terms of common business cycles using the common features test. Cheung and Yuen (2005) and Sato and Zhang (2006) find evidence of common business cycles. However, I cannot confirm this finding in the sample 2000Q1 – 2021Q1.

Prior to the common features test, a few preliminary analyses were performed. A visual inspection of the seasonal growth rates of logged, not seasonally adjusted, real GDP data and the calculation of corresponding correlation coefficients reveal several dissimilarities between the GDP growth rates of China and the individual countries. This impression continues when examining the autocorrelation functions. The cyclical impulse response patterns differ greatly from each other. Overall, China seems to have a much longer cycle than the other considered East Asian countries. After the preliminary seasonal unit root and seasonal cointgeration tests, the common features and codependency test are estimated. They confirm the result of the preliminary analyses and show little evidence for common cyclical elements. Identical impulse response patterns with China are rejected for all countries considered. In the robustness analysis, again, the alternative canonical correlation-based SCCF test is used. In addition, the impact of the COVID-19 crisis is considered, and the analysis is repeated in a corresponding shorter sample. The main result of no common business cycles between the investigated East Asian countries and China remains. Slightly more evidence for common cyclical elements is found when using the alternative test and excluding the COVID-19 pandemic.

In the following section, reasons for the differing results compared to previous studies are examined in more depth. Possible reasons for the different results might be the earlier period considered or the use of seasonally adjusted real GDP data in earlier studies which may lead to more evidence for common business cycles. Therefore, I re-ran the analysis for the sample considered by Cheung and Yuen (2005), 1994Q1 – 2002Q4, and the countries considered by them, China, Hong Kong, and

Taiwan. Under these conditions, I can confirm the result of previous studies, although the impression of the preliminary analyses contradict it. In the formal estimation of the test, however, the small number of observations could also lead to the null hypothesis that there are common business cycles not being rejected.

Section 2.7 summarizes the findings of the second part of this thesis. We add to the literature on optimal currency areas and introduce common autocorrelation as and additional OCA criterion. We use a conceptual framework to demonstrate that the SCCF test used in the literature is indeed the appropriate testing procedure. Regarding the acceding countries to the euro area, we find little evidence for identical impulse response patterns, except for Sweden. Thus, only Sweden would form an optimal currency area with the euro area aggregate according to our proposed criterion of identical reaction to exogenous shocks. The less strict codependence of order one, which allows for an initial different reaction, could also be relevant for the analysis of optimal currency areas, however, this does not follow directly from our model. For East Asian countries and China, there is even less evidence of common impulse response patterns. Although the institutional analysis demonstrates that the countries and China are converging, this finding is not yet sufficient for closer monetary cooperation and possible welfare effects should be taken into account when considering it.

Bibliographic information

Parts of the paper are based on articles written with co-authors. Moreover, some of the results have already been published.

Part 1, “Currency Internationalization,” is and extended version of

Cheung, Y. W., Grimm, L., & Westermann, F. (2021). The evolution of offshore renminbi trading: 2016 to 2019. *Journal of International Money and Finance*, *113*, 102369.

In addition to various extensions, in particular, sections discussing the international role of the euro have been added.

Part 2, “Exchange Rate Regime Choice,” is an extended synthesis of

Grimm, L., Steinkamp, S., & Westermann, F. (2021). On Optimal Currency Areas and Common Cycles: Are the Acceding Countries Ready to Join the Euro? *CESifo Working Paper No. 9016.*

Grimm, L. (2022). A Renminbi Block for East Asia? A Re-evaluation of Business Cycle Co-movements. *CESifo Area Conference on Global Economy.*

In addition to various extensions, in particular, Sections 2.2, 2.5.1, 2.5.3.4, 2.6.3.4, and related discussions have been added, thus expanding the above-referenced articles.

1 Currency Internationalization

1.1 Introduction

An international currency is characterized by the fact that it is not used exclusively by residents of the issuing country. The proportion to which non-residents use the currency relative to other currencies describes the role that the currency plays internationally. Lim (2006), Chinn and Frankel (2008), Thimann (2008), and Siranova and Rocha (2020), for example, discuss factors that affect the international use of a currency. These include trade in goods; financial markets and their openness; the stability of and confidence in a currency; and the size, strength, and international integration of the real economy of the issuing country. These factors are related to the dimensions of currency use: medium of exchange, unit of account, and store of value. In an international context, currencies can be used by public entities or private actors in these dimensions.[6] Public entities use currencies as intervention currencies, anchor or peg currencies, or reserve currencies, while private actors use currencies as vehicle and invoicing currencies, quotation currencies, investment currencies, and financing currencies.

Several factors cause the intensity of use of some currencies to outweigh others. Network externalities, for example, lead to the advantage of using the currency that is also used by others (Matsuyama et al.; 1993; Rey, 2001; He and Yu, 2016; Berthonnet and Bracarense, 2022). Meissner and Oomes (2009) analyze the role of currencies used by trading partners.

In the past, there were some dominant international currencies, such as the Florentine fiorino, the Venetian ducat, the Dutch guilder (in the 17th and 18th centuries), and the pound sterling until World War I. Currently, since the interwar period, the U.S. dollar has clearly dominated international markets. Before and soon after the introduction of the euro, discussions occurred in the economic literature about which currencies would shape the international monetary system, whether the euro could replace the dollar, and

[6] The European Central Bank regularly monitors and reports on the international use of the euro. Among other things, it evaluates the share of the euro in the international reserves of foreign central banks, the use of the euro as a currency in international contracts outside the EU, and the volume of euro-denominated international debt securities (see various reports on "The International Role of the Euro" by the ECB).

what status the Japanese yen would have. Later, the discussion focused on an analysis of why the euro did not overtake the dollar and what role the Chinese renminbi would play.[7] Cheung (2015), Cheung and Yiu (2017), Cheung et al. (2019), and Westermann (2023) add studies on the geographical spread of a currency and underlying determinants to the discourse.

Unlike the establishment of most other currencies, the euro was introduced as a joint successor to several established currencies, initially replacing 11 – and now 20 – national currencies. However, after its introduction, the share of the euro in FX transactions did not correspond to the sum of these previously existing currencies. The triennial surveys on the global FX market conducted by the Bank for International Settlements offer information on currency trading around the world. According to data from the first survey after the introduction of the euro, which covers data from April 2001, the share of euro transactions was only 38%. However, this still made the euro the second most widely used currency after the U.S. dollar. The share in 2001 was higher than the German mark transactions in the prior 1998 survey (30%), but the sum of the predecessor currencies of the euro was significantly higher, at 53%.[8]

While a strong international role of the euro was still assessed as a sign of confidence of the rest of the world in the Economic and Monetary Union (EMU) – but was not claimed as a policy target in the European Central Banks (ECB) publication on the international role of the Euro in 2017 (European Central Bank, 2017) – the communication changed in 2018. The state of the union address by Jean-Claud Juncker in September 2018, as well as the European Commission's December 2018 communication, highlighted the strategic importance of the single currency and outlined key actions to foster the international role of the euro (Juncker, 2018; European Commission, 2018). The European Commission (2021) has emphasized that a strong international role of the euro is important for achieving the economic and financial strategic autonomy of the EU and the strengthening and deepening of the single market.

[7] See, among others, Portes and Rey (1998), Detken and Hartmann (2002), Hartmann and Issing (2002), Cohen (2003), Eichengreen and Flandreau (2009), Eichengreen (2011), He and Yu (2016), Ilzetki et al. (2020).

[8] Since two currencies are involved in each transaction, the total is 200%.

The first key action in its communication paper with other EU institutions was thus to make progress toward a completed banking union and a capital markets union to deepen the EMU. A further plan was to promote the international use of the euro and of euro-denominated instruments, especially in key strategic sectors, such as energy, raw materials, and transport.[9,10]

Hudecz et al. (2021) agree that progress toward a completed banking union and a capital markets union will increase the attractiveness of the euro for international investors, but they further argue that the spread of the euro will also be influenced by developments in emerging markets, especially China. The aspiring RMB can challenge not only the U.S. dollar but also the euro. At the same time, a higher weighting of the euro in China's currency basket, for example, could increase the euro's international status. However, the China Foreign Exchange Trade System (CFETS) effectively reduced the weights of the U.S. dollar and euro in the CEFTS basket starting in 2023. Since 2017, the share of the euro in the RMB basket has increased and has had a weight of 16.34% in the currency basket since 2017, 17.4% since 2020, and 18.45% most recently. With effect from the beginning of 2023, the weight of the euro was reduced to 18.21% (CFETS, 2016; CFETS, 2019; Reuters, 2022; Cheung, 2022).

China is a major global player, and is linked to the rest of the world via a vast and complex trade network. Indeed, the role of the RMB as an international currency has been quickly progressing since China approved the pilot scheme of RMB cross-border trade settlement in 2009.[11] The inclusion of the RMB in the basket of SDR currencies in 2016 is lauded as a validation of China's efforts to internationalize the RMB, and SDR membership is perceived to catapult the RMB's global status.

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[9] The communication also includes information on the current role of the euro and the benefits of a stronger international role (European Commission, 2021). See also European Central Bank (2021) and Council of the European Union (2022).

[10] Different countries have different policy stances on internationalizing their currencies. For example, see Eichengreen and Flandreau (2009) for the U.S. policy to support the U.S. dollar's global role and Ministry of Finance, Japan (2003) for the case of Japanese yen. The Bundesbank was perceived reluctant to globalize the German mark before the euro era (Franke, 1999).

[11] The use of RMB to settle cross-border trade could be traced back to at least 2003 (State Administration of Foreign Exchange, 2003a, 2003b). However, these cross-border settlements in the RMB were adopted to reduce the burden of using hard currencies such as the U.S. dollar and not a policy to internationalize the RMB.

China has strategically guided the use of the RMB overseas; anecdotal evidence suggests that its offshore use was initially concentrated around the Asian region and then gradually spread to other parts of the world.[12] Eichengreen et al. (2016), He et al. (2016), He and Yu (2016), Mehl (2017), and Wójcik et al. (2017), for example, discuss the economic, political, and technical factors that affect the offshore trading of international currencies. The U.S. dollar, arguably the most predominant global currency, illustrates the complementary and supporting roles of offshore markets in popularizing dollar transactions around the world.

In the last 10 years, China has introduced strategic policies to establish its network of offshore RMB markets and advance its currency's global status. These policies include (a) the establishment of RMB clearing banks in offshore markets to facilitate settlements of RMB transactions overseas; (b) the signing of bilateral RMB currency swap agreements to provide emergency RMB liquidity; and (c) the provision of RMB qualified foreign institutional investor (RQFII) quotas that allow investing offshore RMB in China's onshore bond and equity markets. These arrangements encourage the international use of the RMB and facilitate the development of offshore trading in regional, international, and global settings.

The data provided by SWIFT attests that cross-border uses of the RMB have experienced a sharp increase since the early 2010s. For instance, the RMB was the 20th most used world payments currency by value in January 2012 and, in less than four years, it became the fifth-ranked currency by December 2014 (SWIFT, 2012; 2015b). The stellar performance of the RMB as a world payment currency also reflects China's emphasis on trade facilitation and its strong presence in international trade.

According to the BIS surveys, While the global FX market grew by about 70% between 2010 and 2019, the offshore RMB turnover increased almost eightfold (Bank for International Settlements, 2010, 2019). The rapid growth in offshore trading contributes to the fast expansion of RMB turnover and occurs concurrently as the RMB transitions from a regional to a global role.

[12] See, for example, Cheung (2015), Ehlers and Packer (2013), Ehlers et al. (2016).

Does the fast growth of offshore RMB markets follow a specific geographical evolution pattern? For instance, will offshore trading converge to a geographical pattern similar to that of global FX trading? Cheung et al. (2019) posit that "a currency undergoing internationalization experiences a characteristic evolution of its geographical distribution of trading outside its home jurisdiction." In the case of the RMB, its offshore trading pattern will transition from an initial regional one toward the global FX trading pattern over time. Using data from the Bank for International Settlements (2013, 2016), these authors showed that offshore RMB trading indeed appears to converge to the spatial global FX trading pattern.

Despite its fast penetration, the RMB in terms of both scope and scale is a small player in the global financial system, relative to the sizes of China's economy and trade sector. Furthermore, global RMB trading displayed a growth rate between April 2016 and April 2019 that was slower than that between April 2013 and April 2016 and occured mostly within the Asian region, with a wider spread to other regions (Bank for International Settlements, 2016, 2019; Cheung, 2015; Ehlers and Packer, 2013; Ehlers et al., 2016). Despite these observations, China's efforts to internationalize the RMB offer a unique opportunity for analyzing the process of internationalizing a currency in the presence of binding capital controls and targeted policy-driven initiatives.[13]

Mundell (1961) aptly notes that "[…] currencies are mainly an expression of national sovereignty, so that actual currency reorganization would be feasible only if it were accompanied by profound political changes." Being symbolic of a country's economic heft and its predominance in the global economy, the international political environment will thus influence a currency's internationalization experiences.

Since Donald Trump entered the White House in the midst of China's expanding foreign policy ambitions under the Xi Jinping regime, China has encountered an increasingly confrontational geopolitical environment. In addition to the China–U.S. dispute, China in recent years engaged in political disputes with a few other countries, including Japan and Korea, that resulted in various kinds of trade actions. Conceivably,

[13] The evolution of the major global currencies, including the U.S. dollar, occurred before reasonably comprehensive BIS surveys of FX turnover were available.

these disputes and the related bellicose rhetoric can adversely affect the environment under which China conducts trade and financial businesses with these countries and can affect global investors' views and commitments, at least temporarily, on the RMB. In the following, my co-authors, Yin-Wong Cheung and Frank Westermann, and I assess whether disputes and recent changes in geopolitics have implications for the penetration pattern of offshore RMB markets.

Against this backdrop, we study the evolution of the offshore RMB trading pattern between 2016 and 2019 and assess the determinants of the pattern of changes across offshore financial centers. Cheung et al. (2019) assess the geographical distribution hypothesis with three variables that describe the FX turnover initial conditions, gaps between initial shares of RMB and total FX trading volumes, and changes in the share of total FX trading. In this study, we postulate that, in addition to these three FX market variables, offshore RMB trading between 2016 and 2019 was affected by the changing geopolitical environment. Specifically, in view of the debilitating effects of disputes and China's emphasis on the facilitation of international trade, we investigate the roles of disputes, trade relationships, China's policies, other links to China, and the characteristics of the offshore financial center in determining the geographical evolution of RMB shares.

To anticipate results, we find that, once the effects of the dispute and trade intensity are accounted for, offshore RMB trading was transitioning toward the global FX trading pattern between 2016 and 2019. In addition to the three variables that capture global FX market conditions, the dispute- and trade-related variables have statistical and economic implications for the evolution of offshoring RMB trading. Specifically, we find that engagement in disputes with China implies a negative impact on the offshore RMB share between 2016 and 2019. The "dispute effect" is, however, mitigated by bilateral trade volume. The bilateral trade variable by itself does not display a significant effect – its significance is observed via the interaction with the dispute variable. This finding suggests that the dispute variable – our proxy for geopolitical factors – is a relevant factor for the current sample and that existing economic linkages represented by trade relationships modify its implications. The inclusion of the dispute- and trade-related variables and their interaction helps to reveal the tendency to converge to the global FX trading pattern and discernibly improves the regression's explanatory power.

The geographical offshore RMB trading pattern is also affected by both China-specific policies and the characteristics of offshore markets. Specifically, China's RQFII quotas and the host country's levels of equity market capitalization and financial development positively enhance offshore RMB trading. It is further affirmed that the 2016-2019 dynamics differ from the 2013-2016 one – the latter dynamic process is mostly characterized by convergence behaviour, as reported before.

The next section provides a brief overview of RMB internationalization in the last decade, noting the interweaving of policy- and market-driven dynamics. Sections 1.3, and 1.4 examine the evolution of the geographical distribution of offshore RMB and euro trading, respectively, between 2016 and 2019 using the three FX market variables and additional determining factors. For the RMB, the roles of disputes, trade relationships, China's policies, links to China, and offshore financial center's characteristics are evaluated. Adapted to the euro, additional determinants come from the areas of links to the euro area and the economic and institutional characteristics of the respective trading centers. Section 1.5 offers some concluding remarks.[14]

[14] Parts of this section are based on joint work with Yin-Wong Cheung and Frank Westermann and have already been published (see Cheung et al., 2021). In particular, sections discussing the international role of the euro have been added.

1.2 Internationalization of the Renminbi – A Brief Overview

Since the 2009 pilot cross-border trade settlement scheme, China has implemented policy initiatives to promote and facilitate the use of the RMB overseas.[15] Indeed, to prepare for cross-border transactions, China stealthily launched its initiative to develop offshore RMB centers in 2003 by authorizing an RMB clearing bank in Hong Kong – the first facility of its kind outside mainland China. The trade settlement scheme was expanded to cover the whole of China in August 2011, from the initial group of five cities, including Shanghai and four cities in Guangdong Province.

Given its unique political and economic characteristics, Hong Kong has been a testing ground for experimenting policies that promote the use of the RMB overseas.[16] The policies for promoting offshore RMB business have typically been first introduced in Hong Kong before extending to other regional and international financial centers. Three of these promotional policies – sometimes dubbed the "three gifts" – are the appointment of local RMB clearing banks, the setup of bilateral RMB currency swap agreements, and the assignment of RQFII quotas.[17] Other related policy initiatives include stock-connect and bond-connect programs, the issuance of dim sum bonds, the issuance of RMB denominated equities in market overseas, and the Belt and Road Initiative.

The policy push, albeit in a measured manner, has put the RMB in the limelight. In the last decade, the global market has witnessed a surge in RMB-related business activities that have gradually spread from the Asian region to other parts of the world. The rapid global penetration, coupled with China's economic prowess, prompted the International Monetary Fund to designate the RMB an SDR currency in November 2015.[18]

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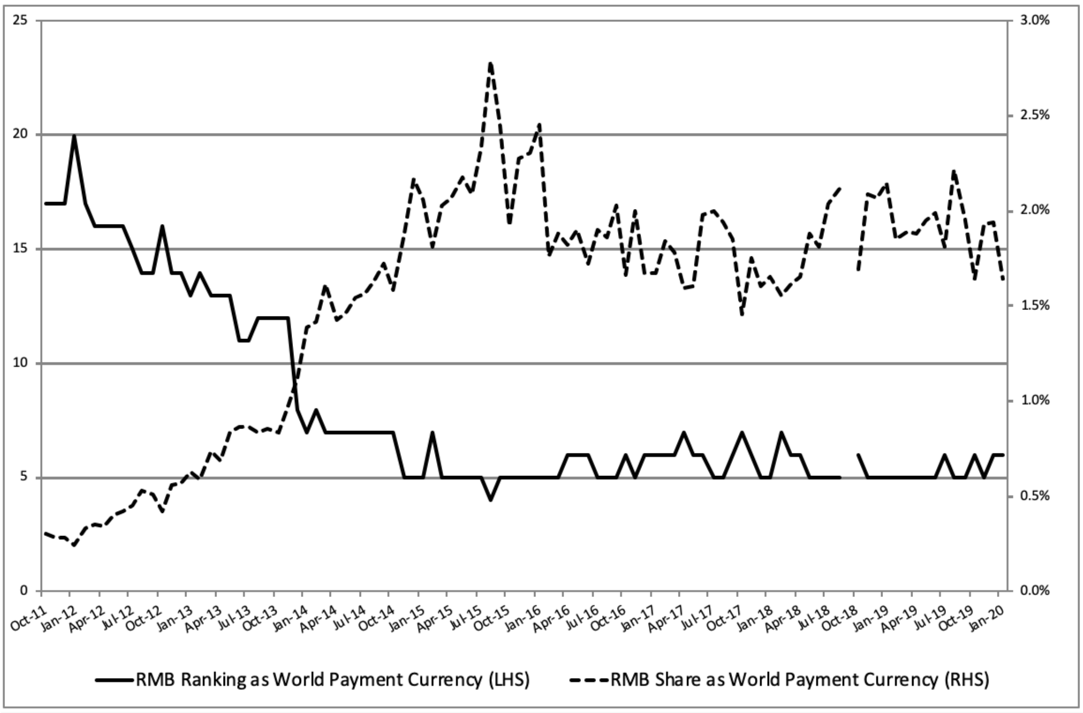
[15] Studies on RMB internationalization include Cheung et al. (2011), Eichengreen (2013), Eichengreen and Kawai (2015), Frankel (2012), and Prasad (2016).
[16] While China has sovereignty over Hong Kong, it considers Hong Kong an "offshore" market for RMB transactions.
[17] On September 10, 2019, China announced the removal of the quota limitation on the RQFII program (State Administration of Foreign Exchange, 2019), which took effect on June 6, 2020.
[18] On October 1, 2016, the RMB officially joined the SDR basket with a 10.9% weight. The weights of the other four SDR currencies were the U.S. dollar (41.7%), euro (30.9%), Japanese yen (9%), and British

The growing role of the RMB in the global market is illustrated by its trading in the global FX market. The BIS triennial central bank surveys present a detailed account of RMB turnover in the global FX market. According to the surveys, the average daily RMB FX turnover in the global market surged from 29.2 billion USD in 2010, to 119.6 billion USD in 2013, to 202.1 in 2016, and to 285.0 billion USD in 2019, and its share of global FX trading increased to 4.3% in 2019 from a mere 0.9% in 2010 (Bank for International Settlements, 2010, 2013, 2016, 2019).

Figures 1.1 and 1.2 offer two alternative views on the RMB's evolving global role. Figure 1.1 is based on SWIFT data on currency usage for world payments. In a decade, the share of world payments accounted for by the RMB increased from 0.29% at the end of 2011 to 1.65% in January 2020, and its rank improved to sixth from 20th (SWIFT, 2012, 2020).

Figure 1.1 The RMB as a Global Payment Currency

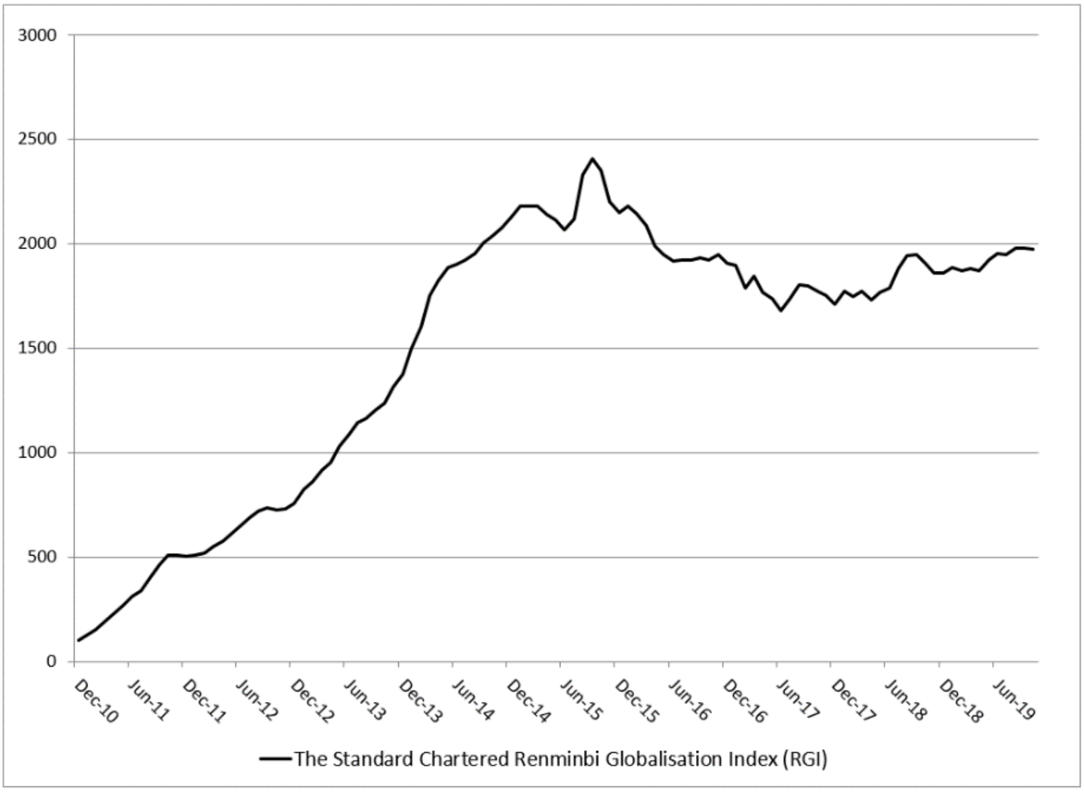


Source: SWIFT RMB Tracker (various issues)

pound (8.1%). Every 5 years, the IMF reviews the weighting of the currencies in the basket. Since August 1, 2022, the currencies have been assigned the following weights: U.S. dollar (43.38%), euro (29,31%), RMB (12.28%), Japanese yen (7.59%), British pound (7.44%) (International Monetary Fund, 2022).

Figure 1.2 plots the Renminbi Globalization Index compiled by Standard Chartered Bank, which tracks the level of RMB internationalization by assessing offshore RMB business activities.[19] The index started in December 2010 with a base value of 100, reached a height of 2,405 in September 2015, and settled at 1,974 in October 2019.

Figure 1.2 The Standard Chartered Renminbi Globalization Index



Source: Standard Chartered Bank (2019)

Despite the fact that the RMB's global share has increased from less than 1% to 4.3% and improved from being the 17th most traded currency to the eighth between the 2010 and 2019 BIS triennial surveys, the turnover is still low compared with China's economic size and international trade. Table 1.1 lists the ratios of daily turnover to GDP and to international trade volume of the top 10 most actively traded currencies in the 2019 BIS triennial survey. Because each FX transaction involves two currencies, the sum of the percentage shares of individual currencies totals 200%.

The RMB's daily FX turnover to GDP and to international trade ratios are, respectively, 2.09% and 6.17%, the smallest among the top 10 currencies. Relative to its

[19] The index is designed to measure overall offshore RMB usage (Standard Chartered Bank, 2019).

economic size and international trade volume, the New Zealand dollar is the most heavily traded currency. Notably, the currency of Hong Kong, a special administrative region of China comprising 2.6% of China's economy size, ranks as the ninth most traded currency, accounts for 3.5% of global turnover, and has larger FX turnover to GDP and to international trade ratios than the RMB.

Table 1.1 FX Average Daily Turnover, Economic Size, and International Trade Volume

	Turnover Share (%)	Turnover/GDP (%)	Turnover/Trade (%)
USD	88.30	27.98	138.27
EUR	32.28	15.80	22.13
JPY	16.81	22.42	75.44
GBP	12.79	29.65	72.49
AUD	6.77	31.31	90.11
CAD	5.03	19.51	35.66
CHF	4.96	46.73	56.97
CNY	4.32	2.09	6.17
HKD	3.53	63.67	19.70
NZD	2.07	66.84	163.27

Notes: The Table lists the top ten most actively traded currencies in the 2019 BIS triennial survey (US dollar, euro, Japanese Yen, British pound, Australian dollar, Canadian dollar, Swiss franc, Chinese renminbi, Hong Kong dollar and the New Zealand dollar), and their FX average daily turnover shares, daily turnover to GDP ratios, and daily turnover to international trade ratios. Data on FX turnover are from BIS (2019), and data on GDP and international trade volume from Q2 2018 to Q1 2019 are from, respectively, IMF International Financial Statistics (IFS) and IMF Direction of Trade Statistics (DOTS).

The fast ascent of the RMB internationalization process is not monotonic. Figures 1.1 and 1.2 both demonstrate that the RMB internationalization process shows an inflection point around August 2015.[20] After reaching a high of 2.79% in August 2015, the RMB's share in global payments had drifted down to 1.65% by January 2020 (Figure 1.1).[21] The Renminbi Globalization Index similarly shows that offshore RMB business has slowed since September 2015 (Figure 1.2). While RMB FX trading increased in the 2019 BIS triennial survey, the growth of RMB turnover is lower than that of the 2016

[20] On August 11, 2015, China modified its official RMB central parity formation mechanism (People's Bank of China, 2015).
[21] The Hong Kong dollar ranked eighth and accounted for 1.40% of worldwide payments in January 2020 (SWIFT, 2020).

survey, and this slower growth has coincided with the relatively slower growth of offshore RMB trading (Packer et al., 2019; Schrimpf and Sushko, 2019).

The propagation of the RMB in the global market has faced different domestic and global conditions in the last few years. For instance, China introduced various capital control measures in response to the market turmoil that followed the August 2015 modification of the RMB central parity formation mechanism. These capital control measures, aimed at reining in capital outflow and capital repatriation, discouraged foreigners from committing to RMB businesses.

The dispute between China and the US – the two largest countries in the world – under Donald Trump's presidency further impeded the RMB internationalization process.[22] For instance, tariffs and the re-revamping of global supply chains triggered by trade disputes affect China's interactions with the rest of the global community. The disrupted global production chain and economic uncertainty affect China's trade and economic relationship not only with the US but also with its allies.

Besides disputes with the US, China has in the last few years engaged in diplomatic rows with other countries that are at times bellicose, including the notable examples of Japan and Korea. China usually reinforces its belligerent rhetoric with, for example, trade restrictions against related countries. Countries are alarmed by China's assertive diplomacy approach and must re-assess their economic ties with China and the benefits of adopting the RMB for international transactions. The disputes triggered by economic (and political) discord can divert countries from the global use of the RMB.

Cheung et al. (2019) hypothesize that the geography of offshore RMB trading will over time transition toward the geographical distribution of global FX trading. They show that the data from the Bank for International Settlements (2013, 2016) supports this hypothesis, and that the pattern of RMB shares of offshore financial centers appears to converge to the spatial global FX trading pattern. The convergence result, however, is obtained with the 2013 and 2016 data, which were *not* seriously affected by the disputes

[22] Growing populism and the reversal of globalization also do not favor the globalization of the RMB.

between China and other countries in the last few years.

While the changing environment has not completely stalled the RMB's internationalization process, it can affect the evolution of its offshore trading across financial centers. With geopolitical conditions turning confrontational, we stipulate that disputes and trade relationships with China, in addition to other factors, can have affected the global usage of the RMB and, hence, the evolution of offshoring RMB trading across financial centers between 2016 and 2019.

In the next section, we follow previous studies and employ data from the BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Turnover to study the evolution of offshore RMB trading across financial centers. Specifically, our analysis focuses on the RMB turnover data from the 2016 and 2019 surveys. In addition, we briefly discuss some further results on offshore RMB trading between 2013 and 2016 and on offshore trading of three of the four other SDR currencies (U.S. dollar, Japanese yen, British pound); offshore euro trading is examined in more detail in Section 1.4.

1.3 Empirical Analyses – Renminbi

1.3.1 The Basic Specification

The geographical evolution of RMB offshore trading between 2016 and 2019 is investigated using FX turnover data reported in the 2016 and 2019 BIS triennial surveys (Bank for International Settlements, 2016, 2019). Excluding China, which has a domestic RMB market, our sample includes central banks and other authorities in 50 jurisdictions[23] reporting RMB trading. For convenience, we use the terms "jurisdiction" and "financial center" interchangeably, without any legal connotations. The basic cross-sectional regression specification is

$$\Delta Y_{i,19} = \alpha + \beta Z_{i,16} + \gamma \Delta X_{i,19} + \delta W_{i,16} + \mu D_i + \zeta BT_{i,19} + \lambda BT_{i,19} * D_i + \varepsilon_i. \quad (1)$$

The dependent variable, $\Delta Y_{i,19} \equiv Y_{i,2019} - Y_{i,2016}$, measures the change in the share of RMB trading experienced by the i-th jurisdiction between 2016 and 2019, where $Y_{i,2019}$ is jurisdiction i's share of offshore RMB trading given by the ratio of its average RMB daily turnover to the average global offshore RMB daily turnover reported in the 2019 BIS triennial survey. Table A1.1 and A1.2 in Appendix I list the definitions, sources, and descriptive statistics of the variables in equation (1) and other variables considered in the rest of the current study.

There are two groups of explanatory variables in our basic specification. The first group comprises $Z_{i,16}$, $\Delta X_{i,19}$, and $W_{i,16}$. These three variables are proxies for FX market information used to examine changes of offshore RMB trading shares (Cheung et al., 2019). In our exercise, we interpret that they also capture the relevant general market-based information.

[23] The jurisdictions are Argentina, Australia, Austria, Bahrain, Belgium, Brazil, Bulgaria, Canada, Chile, Colombia, Czech Republic, Denmark, Finland, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, South Korea, Latvia, Lithuania, Luxembourg, Malaysia, Mexico, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Singapore, Slovakia, South Afrika, Spain, Sweden, Switzerland, Thailand, Turkey, the United Kingdom, and the United States.

The change in jurisdiction i's share of global FX trading is given by $\Delta X_{i,19} \equiv X_{i,2019} - X_{i,2016}$, where $X_{i,2019}$ is jurisdiction i's share of 2019 global currency trading, given by the ratio of its average daily FX turnover to global FX turnover. The variable is included to assess the implication of a jurisdiction's standing in global FX trading for its RMB share.

The convergence toward the global FX trading pattern is captured by the gap variable, $Z_{i,16} \equiv Y_{i,2016} - X_{i,2016}$, which represents the gap between jurisdiction i's share of offshore RMB trading and its share of global FX trading. The gap variable $Z_{i,16}$ is one of the key variables of the exercise. When the RMB is transitioning to be a global currency, one anticipates the process will reduce the gap between an initial geographic trading distribution and the distribution pattern of global FX trading. Under this stipulation, we expect the β-coefficient to be negative.[24]

The correlation estimate is 0.5357 between the 2016 shares of offshore RMB trading ($Y_{i,2016}$) and global FX trading ($X_{i,2016}$), is 0.4940 between $Y_{i,2019}$ and $X_{i,2019}$, and is 0.4247 between $Y_{i,2013}$ and $X_{i,2013}$. The increase between the 2013 and 2016 correlation estimates is in accordance with the notation that the offshore RMB trading pattern is converging toward the global FX trading pattern. However, the 2019 correlation estimate is smaller than the one of 2016; this indicates that the two patterns are becoming relatively dissimilar and that the RMB has not transitioned closer to a trading pattern similar to that of all FX trading between 2016 and 2019. In the following, we investigate whether the inference based on bivariate correlation carries over to multivariate regression analyses.

The variable $W_{i,16}$ gives jurisdiction i's RMB turnover as a share of its total FX turnover and is included to account for the initial relative importance of RMB trading.

The second group of explanatory variables, D_i, $BT_{i,19}$, and $BT_{i,19}{*}D_i$, are included to capture the possible effects of specific geopolitical conditions faced by the promotion of RMB uses overseas. On top of disputes with the U.S., China's image and its

[24]An acute reader will note that the dependent variable $\Delta Y_{i,19}$ and the gap variable $Z_{i,16}$ share a common component, $Y_{i,2016}$. Under some distributional assumptions, we can derive a specific correlation between $\Delta Y_{i,19}$ and $Z_{i,16}$. Nevertheless, the gap variable effect reported in the subsequent multiple regression exercise (i.e. Table 1.2, Column (1)) is not likely attributed to this observation.

interactions with the global community are gradually altered by the assertive foreign policy approach adopted by Xi Jinping's regime.[25] For instance, in the past few years, China has engaged in some serious disputes that triggered economic consequences with, Japan, Korea, Singapore, and Australia. To capture the effects of these disputes on offshore RMB trading, the dummy variable D_i assumes a value of 1 for financial centers in the US, Japan, Korea, Singapore, and Australia.

The U.S. is selected as the China – U.S. dispute has been in international headlines in the last few years. The ebbs and flows of the China – Japan relationship is overshadowed by the intensified territorial dispute surrounding the Diaoyu/Senkaku Islands that triggered sanctions against Japanese businesses and against trade between the two countries (Li and Liu, 2019). In response to Korea's decision to deploy THAAD (a U.S.-based missile defense system), China launched belligerent rhetoric against the decision and initiated various sanctions against Korean business in China and in Korea (Han, 2019).[26] China's displeasure with Singapore's ties with Taiwan was dramatically voiced by its seizure of nine armored vehicles that Singapore shipped through Hong Kong after a training exercise in Taiwan in November 2016, as well as not inviting Singapore to its Belt and Road Initiative meeting in 2017.[27] Lastly, the relationships between China and Australia have become strained since Australia warned of growing China's influences on its politics in 2017[28] and reached a low point when Australia called for an investigation of the source of COVID-19 in 2020.[29] China has imposed sanctions on beef, barley, and coal, as well as an anti-dumping tariff of more than 200% on wine.

Even though these confrontational episodes may be short-lived, they affect China's goodwill and trustworthiness and can swerve or weaken commitments to adopt the RMB for international transactions. Thus, we expect the dispute dummy variable D_i to have a negative coefficient.

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[25] See, for instance, Anderlini (2020).
[26] Meick and Salidjanova (2017) offer an account of China's response to the THAAD deployment.
[27] Singapore is the only Southeast Asian country with an economic partnership agreement with Taiwan. Singapore also hosts U.S. military forces and is viewed as being on the U.S. side in the China – U.S. dispute (Lee, 2019). Its return of faulty MTR trains to China in 2016 is another sign of the strained relationship.
[28] Citing national security reasons, Australia banned the Chinese Huawei from its 5G network project in 2018.
[29] See, for example, Trian (2020).

China's foreign exchange and trade policies are closely related – the foreign exchange policy is typically devised with trade facilitation in view. For instance, in the early phase of the cross-border trade settlement program, authorities were urged to ensure that offshore RMB transactions were supported by genuine cross-border trades.[30] Jurisdiction i's variable $BT_{i,19}$, given by the sum of its imports from and exports to China normalized by its total international trade volume between April 2018 to March 2019, is included to capture the trade effect on offshore RMB trading. According to People's Bank of China (2020), 13.4% of the total cross-border goods trade was settled with the RMB. Thus, the trade volume itself – rather than its change – provides a good and a less noisy proxy for the potential increase in using RMB in settling trade.[31] We expect the variable $BT_{i,19}$ to have a positive coefficient.

The effects of the two variables D_i and $BT_{i,19}$ are likely to influence each other. For instance, the intensity of trade relations can affect the retaliation induced by disputes, while both affect the desirability of offshore RMB trading. Compared with $BT_{i,19}$, which reflects complementary economic benefits that have long-term implications for offshore RMB trading, the dispute variable D_i would plausibly have a rather short-term effect. The elected politicians that foster these confrontational episodes have limited terms in office, and disputes can quickly subside when a new government comes into power. For instance, as a Democratic candidate for President, Joe Biden vowed to re-evaluate President Trump's tariffs on imports from China upon taking office.[32] In view of trade's mutual beneficial nature, a dispute in the presence of a high trade volume is unlikely to be credible in the longer term. We thus stipulate the interaction term $BT_{i,19}*D_i$ to have a positive coefficient: a high trade volume would mitigate the negative dispute effect.

[30] See, for example, Hong Kong Monetary Authority (2010).

[31] When the change in trade volume, instead of the trade volume itself, was used in the subsequent regression exercise, it yielded qualitatively similar significant coefficient estimates but noticeably reduced the overall explanatory power as measured by adjusted R^2 estimates (see Appendix I, Table A1.3).

[32] See, for example, Anderson (2020). Of course, after election, the newly elected president may change his view or may not be able to implement policy changes as envisioned. Nevertheless, the possibility of such a change illustrates the relative role of the dispute variable.

1.3.2 Empirical Results I – Basic Specification

The results of estimating the baseline equation (1) are presented in Table 1.2. Columns (1) and (2) present results from, respectively, the group of the three FX market variables and the group of the three- dispute and trade-related variables. Column (3) presents the full specification.

Among the three FX market variables, the change in global FX market share ($\Delta X_{i,19}$) is the only one that exhibits a statistically significant effect (Column (1)). When a jurisdiction gains (losses) global FX market share, it tends to experience an increase (decrease) in the share of offshore RMB trading. Both the gap between a jurisdiction's RMB trading share and all-currency trading share ($Z_{i,16}$) and the relative importance of RMB trading to a jurisdiction's total FX trading ($W_{i,16}$) garner a small and statistically insignificant coefficient estimate. The insignificant gap variable $Z_{i,16}$ indicates that, in contrast with 2013 – 2016 data (Cheung et al., 2019), the current 2016 – 2019 sample displays no evidence that offshore RMB trading is transitioning to the global FX trading pattern. However, this insignificant gap variable finding is, as discussed below, not robust to the presence of the dispute and trade related variables.

Under Column (2), the coefficient estimates of the three dispute- and trade-related variables have their expected signs: D_i has a negative coefficient estimate, while $BT_{i,19}$ and $BT_{i,19}*D_i$ have a positive one. However, only the dispute variable is statistically significant; that is, engaging in confrontational rows with China can impair offshore RMB activities.

Results from the full specification highlight the relevance of jointly evaluating the effects of the two groups of determinants (Column (3)). For instance, the adjusted R^2 estimate of 70% obtained from the full specification is noticeably larger than 60%, the sum of the adjusted R^2 estimates from Columns (1) and (2), that is, the three FX market variables and the three dispute- and trade-related variables exhibit complementary effects on changes in the offshore RMB trading share across jurisdictions.

Table 1.2 Changes in Shares of Offshore RMB Trading

Variables	(1)	(2)	(3)	(4)
$Z_{i,16}$	0.005		-0.175***	-0.163***
	(0.14)		(2.90)	(8.43)
$\Delta X_{i,19}$	0.377***		-0.244	-0.062
	(4.53)		(1.29)	(0.83)
$W_{i,16}$	-0.001		0.423***	-0.006
	(0.01)		(3.26)	(0.07)
D_i		-0.054*	-0.079***	-0.043***
		(1.90)	(3.73)	(4.39)
$BT_{i,19}$		0.027	0.008	0.001
		(1.47)	(1.23)	(0.40)
$BT_{i,19}*D_i$		0.181	0.240***	0.148***
		(1.55)	(3.29)	(3.36)
Constant	0.000	-0.001	-0.002**	-0.000
	(0.35)	(0.78)	(2.16)	(0.88)
Adjusted R^2	0.15	0.45	0.70	0.89
Observations	50	50	50	49

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. The results in the absence of the Hong Kong observation are reported under Column (4). *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Considering the three dispute- and trade-related variables, the gap variable $Z_{i,16}$ has a significantly negative coefficient estimate. If a jurisdiction's offshore RMB trading share was larger (smaller) than its total FX trading share, then its RMB share tended to decline (increase) in 2019. Furthermore, if we interpret the total FX trading share as the long-term anchor of the offshore RMB trading share, the negative gap variable effect suggests the offshore RMB trading share is moving toward its anchor over time. The finding is in accordance with the convergence result reported in Cheung et al. (2019).

It should be noted that $Z_{i,16}$ is only one of the determinants that affect the evolution of offshoring RMB trading and that a jurisdiction's total FX trading share is likely to vary over time and be affected by its own determinants. In other words, even though the distribution of offshore RMB trading across financial centers is transitioning toward the geographical distribution of global FX trading, the observed gap between a jurisdiction's offshore RMB trading share and its total FX trading share may not decline linearly over time. A multivariate setting that accounts for other factors affecting offshore RMB trading shares instead of a bivariate setting is likely to be more relevant for studying the transition process.

The coefficient estimates of the total FX market share variable ($\Delta X_{i,19}$) and a jurisdiction's RMB trading share relative to its own total FX trading variable ($W_{i,16}$), under Column (3), have signs and significances that differ from those under Column (1). The coefficient estimates of these two variables are sensitive to the control variables included in the following tables. The sensitivity is in contrast with the negative $Z_{i,16}$ effect, which is quite robustly reported in the presence of these control variables. As such, we infer that the effects of $\Delta X_{i,19}$ and $W_{i,16}$ on changes in offshore RMB trading are not definite.

The coefficient estimates of the three dispute- and trade-related variables, in the presence of the three FX market variables, retain their expected signs. In addition to the dispute variable (D_i), the interaction variable $BT_{i,19}*D_i$ has become statistically significant. While a dispute with China implies a decline in offshore RMB trading, the positive $BT_{i,19}*D_i$ effect suggests that trade intensity can mitigate the negative dispute effect.[33]

Specifically, for a country engaging in a dispute with China, the estimated marginal effect of the dispute on the change in offshore RMB trading share is given by $\hat{\mu} + \hat{\lambda} BT_{i,19}$ and its standard error $[var(\hat{\mu}) + BT^2_{i,19}\ var(\hat{\lambda}) + 2BT_{i,19}\,cov(\hat{\mu},\hat{\lambda})]$. In other words, in addition to the coefficient estimates ($\hat{\mu}$ and $\hat{\lambda}$), the estimated marginal dispute effect depends on the trade intensity variable $BT_{i,19}$. The statistical significance

[33] Similar dispute and trade effects were found with the specification $|Z_{i,2019}| - |Z_{i,2016}| = \beta_0 + \delta W_{i,16} + \mu D_i + \zeta BT_{i,19} + \lambda BT_{i,19}*D_i + \varepsilon_i$, where $|Z_{i,2019}| - |Z_{i,2016}|$ is used to measure "convergence" of the RMB share to total FX share. This specification, however, fits less well to the data and has a lower adjusted R^2 estimate of only 0.50 (see Table A1.4 in Appendix I). None of the Q variables reported as significant in the paper were statistically significant in this regression, so including them did not qualitatively change the results reported in Table A1.4 (see Appendix I, Table A1.5).

of the marginal effect as inferred from its standard error depends on the variances and covariance of $\hat{\mu}$ and $\hat{\lambda}$, and trade intensity with China.

For the five countries included in our dispute variable, D_i, the estimated dispute effects and their standard errors (in parentheses) evaluated at the respective trade variable ($BT_{i,19}$) values are, respectively, United States: -0.043 (0.011), Japan: -0.028 (0.008), Korea: -0.023 (0.007), Singapore: -0.048 (0.013), and Australia: -0.007 (0.007). The U.S. and Singapore garner the two largest dispute effects, while Australia has the smallest effect which is statistically insignificant. The relatively small and insignificant Australian effect may attest to the fact that China stepped up its rhetoric and sanctions against Australia primarily in late 2019 and 2020.[34]

The dispute variable is arguably a rather coarse measure of China's strained relationships with these countries and the specific geopolitical conditions faced by China in the last few years. The variable and its interaction with the trade variable, after controlling for FX market information, illustrate the conceived dispute effects on offshore RMB trading. Despite its simple dichotomous nature, the dispute variable offers results that warrant the further investigation of the effects of political disputes and geopolitical conditions on the propagation of offshore RMB trading across financial centers.

We offer two remarks before assessing the sensitivity of the results reported under Column (3) to the presence of control variables in the next subsection. First, as noted in the previous section, Hong Kong assumes a special role in China's RMB internationalization initiative. With its first move advantage and China's anointment, Hong Kong accounts for a lion's share of offshore RMB business – it accounts for no less than three-quarters of offshore RMB payments (SWIFT, 2020) and over 40% of offshore RMB trading (Bank for International Settlements, 2019). To ensure the results are not overwhelmingly driven by the "extreme" Hong Kong observation, we dropped it, re-estimated (1), and reported the result under Column (4) in Table 1.2. Without the Hong Kong observation, specification (1) yields an adjusted R^2 estimate of 89%, with three statistically significant variables: $Z_{i,16}$, D_i, and $BT_{i,19}*D_i$. The coefficient estimates of

[34] When evaluated at the average of trade values in the sample, the marginal dispute effect and its standard error are, respectively, -0.029 and 0.008.

these three variables are smaller in magnitude but qualitatively similar to the corresponding ones under Column (3). In other words, the main results are not driven by the Hong Kong observation.

The second remark is on the difference between the current 2016 – 2019 sample and the 2013 – 2016 data examined in previous studies. In the preliminary analysis, we formally test the null hypothesis that no structural break exists between the 2013 – 2016 and 2016 – 19 specifications. For the model that includes only the three FX market information variables, the Chow test statistic of 17.5 strongly rejects the no-structural-break hypothesis. For the model given by equation (1), the Chow test statistic of 40.9 also strongly rejects the no-structural-break hypothesis. The two groups of variables exhibit very different effects on the evolution of offshoring RMB trading in the 2013 – 2016 and the 2016 – 2019 sample; specifically, the 2013 – 2016 data are not subject to the geopolitical situations faced by China in the 2016 – 2019 period. It is not efficient and effective to study the evolution of offshore RMB trading with data pooled from the two samples. Thus, we focus on the current 2016 – 2019 sample.[35]

1.3.3 Empirical Results II – Augmented Specification

In this subsection, we assess the sensitivity of the empirical effects of $Z_{i,16}$, D_i, and $BT_{i,19}*D_i$ to the presence of variables accounting for China's policies, links with China, and the economic attributes of the economy in which the financial center is located. Specifically, we augment equation (1) with these additional variables:

$$\Delta Y_{i,19} = \alpha + \beta Z_{i,16} + \gamma \Delta X_{i,19} + \delta W_{i,16} + \mu D_i + \zeta BT_{i,19} + \lambda BT_{i,19}*D_i + \tau Q_i + \varepsilon_i, \quad (2)$$

where Q_i contains the additional explanatory variables. Regression (2) investigates whether these additional variables offer additional power to explain the changes in shares of offshore RMB trading across financial centers.

[35] For completeness, the results from estimating the three FX market variables and the basic specification (1) in alternative samples (2013 – 2016, 2016 – 2019, pooled sample) are reported in Tables A1.6 and A1.7 in Appendix I.

To facilitate the analysis, we classify these additional variables into three categories. The first category comprises the three main policies introduced to promote an offshore RMB center. These policies include the establishment of a) a local RMB clearing bank in the offshore market for clearing cross-border RMB transactions; b) a bilateral RMB currency swap agreement for providing a liquidity backdrop in the event of an RMB shortage; and c) a RQFII quota for accessing China's onshore capital markets. The main stated functionality of the first two policy measures is the provision of RMB liquidity to offshore markets to support trade. The third policy measure enhances the attractiveness of holding offshore RMB. These measures are expected to promote offshore RMB turnover. For the swap line and RQFII policies, we consider the effects of either the presence of such an arrangement or the size of the agreement.

The effects of these policy measures are presented in Table 1.3. The individual marginal effects of these policy variables are presented under Columns (1) to (5); only the variable representing the RQFII quota size is statistically significant and displays the expected positive sign. Column (P) presents the parsimonious specification obtained from sequentially dropping insignificant policy variables from the specification that includes all the policy variables. Either individually or in the presence of other policy variables, the RQFII quota size variable is statistically significant. Its marginal explanatory power is relatively substantial – its presence improves the adjusted R^2 estimate to 85% from 70%. Also, its presence alters the statistical significance of $\Delta X_{i,19}$, $W_{i,16}$, and $BT_{i,19}$; the coefficient estimate of $W_{i,16}$ becomes insignificant, and the coefficient estimates of $\Delta X_{i,19}$ and $BT_{i,19}$ significant (Column (3) in Table 1.2 and Column (P) in Table 1.3). The coefficient estimates of other variables retain their statistical significance while experiencing a slight decline in magnitude. Overall, the inclusion of the RQFII quota size variable helps to explain changes of shares of offshore RMB trading across financial centers, reinforces the trade variable effect, and does not qualitatively affect the effects of the gap variable ($Z_{i,16}$), the dispute variable (D_i), or the interaction variable ($BT_{i,19}*D_i$).[36]

[36] We conducted a robustness check to evaluate the size of the RQFII quota and the size of the swap line agreement standardized by GDP. This does not qualitatively change the results reported in Table 1.3 (see Appendix I, Table A1.8).

Table 1.3 Changes in Shares of Offshore RMB Trading: China's Policies

Variables	(1)	(2)	(3)	(4)	(5)	(P)
$Z_{i,16}$	-0.196***	-0.151***	-0.176***	-0.176***	-0.184***	-0.151***
	(3.05)	(5.11)	(2.97)	(2.88)	(3.01)	(5.11)
$\Delta X_{i,19}$	-0.265	-0.223**	-0.242	-0.248	-0.248	-0.223**
	(1.41)	(2.13)	(1.30)	(1.29)	(1.33)	(2.13)
$W_{i,16}$	0.489***	-0.116	0.435***	0.423***	0.448***	-0.116
	(3.37)	(1.32)	(3.36)	(3.24)	(3.43)	(1.32)
D_i	-0.081***	-0.057***	-0.080***	-0.079***	-0.079***	-0.057***
	(4.05)	(5.24)	(3.76)	(3.71)	(3.87)	(5.24)
$BT_{i,19}$	0.005	0.011*	0.006	0.010	0.009	0.011*
	(1.01)	(1.91)	(0.76)	(1.24)	(1.22)	(1.91)
$BT_{i,19}*D_i$	0.250***	0.163***	0.247***	0.239***	0.241***	0.163***
	(3.63)	(3.83)	(3.34)	(3.27)	(3.44)	(3.83)
RQFII	-0.003					
	(1.00)					
RQFII Size		0.003***				0.003***
		(6.95)				(6.95)
Swap			-0.001			
			(0.76)			
Swap Size				0.003		
				(0.96)		
Clearing Bank					-0.002	
					(0.96)	
Constant	-0.002**	-0.002**	-0.002	-0.003**	-0.002**	-0.002**
	(2.24)	(2.08)	(1.28)	(2.03)	(2.26)	(2.08)
Adjusted R^2	0.71	0.85	0.69	0.69	0.70	0.85
Observations	50	50	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

The second category comprises control variables that quantify links with China, including bilateral FDI flows with China, normalized by the jurisdiction's total FDI flow, and dummy variables that capture the presence of a free trade agreement with China, inclusion in the CFETS,[37] and membership in the Belt and Road Initiative. The latter is included in view of the initiative's asserted intention to connect China with the global economy and promote trade and investment. In addition, we include distance from Beijing (China's capital city) to assess whether the offshore market progression has a regional rather than a global favor. The effects of these linkages are presented in Table 1.4.

Although these selected variables are meant to capture links with China, the results in Table 1.4 indicate that these variables, either individually or jointly, are statistically insignificant (Columns (1) to (5) and (P)). Apparently, the information of these variables that is relevant for the evolution of offshore RMB trading has already been captured by the FX market information, dispute, and trade variables. Once the FX market information, dispute, and trade variables are included in the regression, these link-with-China variables offer no marginal explanatory power.

The third category comprises variables that represent the economic attributes of the economy in which the financial center is located. We follow Cheung and Yiu (2017) and Cheung et al. (2019) and consider real GDP growth rate, equity market capitalization normalized by GDP, size of the international bond market normalized by GDP, and stage of financial development. In essence, these variables are meant to capture the economic strength and financial sector status of a financial center.

The results in Table 1.5 indicate that, among these economic strength and financial sector status variables, only the equity market capitalization variable (Columns (2) and (P)) and financial development index (Column (P)) have a statistically significant coefficient estimate. These two significant variables display the expected positive effect on offshore RMB trading and improve the adjusted R^2 estimate from 70% (Column (P)) to 86%. In other words, the financial market status of a financial center has implications for offshore RMB trading and contains relevant information about the evolution of offshore RMB trading in addition to the FX market, dispute- and trade-related variables.[38]

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[37] CFETS, established in 1994, is an official interbank RMB FX trading platform in China (http://www.chinamoney.com.cn/english/).

[38] The finding of these effects is new, when compared to the earlier results of Cheung et al. (2019), while

Table 1.4 Changes in Shares of Offshore RMB Trading: Links to China

Variables	(1)	(2)	(3)	(4)	(5)	(P)
$Z_{i,16}$	-0.171***	-0.164***	-0.172***	-0.174***	-0.169**	-0.175***
	(2.91)	(3.24)	(2.77)	(2.83)	(2.68)	(2.90)
$\Delta X_{i,19}$	-0.222	-0.197	-0.236	-0.242	-0.234	-0.244
	(1.20)	(1.25)	(1.21)	(1.25)	(1.20)	(1.29)
$W_{i,16}$	0.382***	0.403***	0.409***	0.418***	0.416***	0.423***
	(2.85)	(3.69)	(3.02)	(2.99)	(3.14)	(3.26)
D_i	-0.075***	-0.076***	-0.078***	-0.078***	-0.078***	-0.079***
	(3.74)	(4.23)	(3.60)	(3.68)	(3.60)	(3.73)
$BT_{i,19}$	0.006	0.023	0.011	0.009	0.008	0.008
	(0.98)	(1.47)	(1.49)	(1.03)	(1.13)	(1.23)
$BT_{i,19}*D_i$	0.228***	0.234***	0.235***	0.238***	0.238***	0.240***
	(3.31)	(3.70)	(3.15)	(3.24)	(3.16)	(3.29)
FDI Share	0.020					
	(1.04)					
FTA		-0.005				
		(1.27)				
CFETS			0.001			
			(0.60)			
Log_Distance				-0.029		
				(0.16)		
Belt & Road					-0.001	
					(0.71)	
Constant	-0.002**	-0.003**	-0.003*	0.000	-0.002	-0.002**
	(2.19)	(2.10)	(2.01)	(0.02)	(0.99)	(2.16)
Adjusted R^2	0.71	0.73	0.69	0.69	0.70	0.70
Observations	50	50	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Cheung and Yiu (2017) report the effect of GDP on the early period of offshore RMB trading.

Table 1.5 Changes in Shares of Offshore RMB Trading: Characteristics of Jurisdictions

Variables	(1)	(2)	(3)	(4)	(P)
$Z_{i,16}$	-0.176***	-0.157***	-0.175***	-0.178***	-0.183***
	(2.90)	(3.64)	(2.87)	(2.78)	(5.43)
$\Delta X_{i,19}$	-0.229	-0.160	-0.244	-0.250	-0.184*
	(1.20)	(1.18)	(1.28)	(1.27)	(1.79)
$W_{i,16}$	0.428***	0.153	0.422***	0.431***	0.139
	(3.30)	(1.22)	(3.22)	(3.10)	(1.19)
D_i	-0.080***	-0.065***	-0.079***	-0.079***	-0.061***
	(3.83)	(3.96)	(3.68)	(3.72)	(4.72)
$BT_{i,19}$	0.007	-0.001	0.008	0.008	-0.004
	(1.02)	(0.13)	(1.21)	(1.22)	(0.82)
$BT_{i,19}$*D_i	0.249***	0.214***	0.240***	0.241***	0.208***
	(3.42)	(3.44)	(3.25)	(3.29)	(4.05)
GDP Growth	-0.011				
	(1.00)				
Equity Mkt /GDP		0.005***			0.007***
		(3.34)			(4.05)
Int. Bond Mkt /GDP			0.003		
			(0.30)		
Financial Development				0.001	0.008***
				(0.39)	(4.43)
Constant	-0.002	-0.003***	-0.002**	-0.003	-0.008***
	(1.60)	(3.53)	(2.06)	(1.40)	(5.01)
Adjusted R^2	0.70	0.81	0.69	0.69	0.86
Observations	50	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table 1.6 offers a synthesis of the empirical effects of these three categories of control variables. To conserve the degree of freedom, we consider only those control variables in Tables 1.3 to 1.5 that display a statistically significant effect (Columns (2) to (4)). Column (1) represents the estimation of the baseline regression for easy reference. The parsimonious specification presented under Column (P) indicates that the three control variables retain their significance as reported in previous tables; they jointly enhance the adjusted R^2 estimate from 70%, registered for specification (1), to 89%. In sum, the presence of these control variables helps to explain the changes in the offshore RMB trading share across financial centers but does not qualitatively change the results of transitioning to the global FX trading pattern or the effects of disputes and trade intensity.

Since the dispute variable (D_i) is one of the focal variables of the paper, we also estimated models that include interaction terms between D_i and Q_i (see Appendix I, Tables A1.9, A1.10, and A1.11). In sum, the inclusion of these interaction terms does not have material effects on the coefficient estimates of $Z_{i,16}$, D_i, $BT_{i,19}$, and $BT_{i,19}*D_i$. In other words, the empirical effect of the gap between initial shares of RMB and total FX trading volumes and the variables related to disputes and trade intensities are quite insensitive to the presence of these additional interaction terms. Finally, we also estimate models that include interaction terms between $BT_{i,19}$ and Q_i. Again, the presence of these interaction terms does not materially affect the empirical effects of $Z_{i,16}$, D_i, $BT_{i,19}$, or $BT_{i,19}*D_i$. These results are reported in Appendix I, Tables A1.12, A1.13, and A1.14, respectively.

Note that the RMB is the newest member and the only developing country currency of the SDR basket. The other four SDR currencies, namely, the U.S. dollar, the euro, the Japanese yen, and the British pound, are established global currencies, albeit of different levels of prominence. They arguably acquired their respective status in the international monetary system before the RMB embarked upon its internationalization process a decade ago. A deeper analysis of the diffusion of the offshore euro trading follows in the next section. For the U.S. dollar, the British pound, and the Japanese yen, we do not expect – unlike in the case of the RMB – the offshore trading of these currencies to exhibit a "transition" to the global FX trading pattern during the period under consideration.[39]

[39] These currencies established their global roles before comprehensive BIS surveys of FX turnover were available.

Table 1.6 Changes in Shares of Offshore RMB Trading: A Synthetic Formulation

Variables	(1)	(2)	(3)	(4)	(P)
$Z_{i,16}$	-0.175***	-0.151***	-0.157***	-0.178***	-0.168***
	(2.90)	(5.11)	(3.64)	(2.78)	(6.81)
$\Delta X_{i,19}$	-0.244	-0.223**	-0.160	-0.250	-0.197**
	(1.29)	(2.13)	(1.18)	(1.27)	(2.08)
$W_{i,16}$	0.423***	-0.116	0.153	0.431***	-0.062
	(3.26)	(1.32)	(1.22)	(3.10)	(0.96)
D_i	-0.079***	-0.057***	-0.065***	-0.079***	-0.055***
	(3.73)	(5.24)	(3.96)	(3.72)	(5.63)
$BT_{i,19}$	0.008	0.011*	-0.001	0.008	0.002
	(1.23)	(1.91)	(0.13)	(1.22)	(0.43)
$BT_{i,19}*D_i$	0.240***	0.163***	0.214***	0.241***	0.176***
	(3.29)	(3.83)	(3.44)	(3.29)	(4.24)
RQFII size		0.003***			0.002**
		(6.95)			(2.60)
Equity Mkt /GDP			0.005***		0.004**
			(3.34)		(2.04)
Financial Development				0.001	0.006***
				(0.39)	(3.11)
Constant	-0.002**	-0.002**	-0.003***	-0.003	-0.006***
	(2.16)	(2.08)	(3.53)	(1.40)	(3.35)
Adjusted R^2	0.70	0.85	0.81	0.69	0.89
Observations	50	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Indeed, the estimation of equation (1) (reported in Tables 1.7, 1.8, and 1.9) without the explanatory variables D_i, $BT_{i,19}$, and $BT_{i,19}*D_i$ shows that the changes of offshore trading shares of these three SDR currencies, with the exception of the British pound, are mostly explained by the variable $\Delta X_{i,19}$, which measures the change in jurisdiction i's total FX trading share.[40] Specifically, $\Delta X_{i,19}$ explains 100%, 95%, and

[40] The dispute variable D_i is not included as it is RMB specific. When $BT_{i,19}$ is included, it is insignificant

27%, respectively, of the variability of offshore U.S. dollar trading, offshore Japanese yen trading, and offshore British pound trading.[41]

Table 1.7 Changes in Shares of Offshore U.S. Dollar Trading

Variables	(1)	(2)	(3)	(4)
$Z_{i,16}$	-2.625*			-0.113
	(1.89)			(1.34)
$\Delta X_{i,19}$		1.036***		1.027***
		(91.86)		(80.77)
$W_{i,16}$			0.003	-0.001**
			(0.96)	(2.36)
Constant	-0.000	0.000	-0.003	0.000**
	(0.07)	(0.04)	(1.47)	(2.55)
Adjusted R^2	0.21	1.00	-0.02	1.00
Observations	50	50	50	50

Note: The tables present results from estimating $\Delta Y_{i,19} = \alpha + \beta Z_{i,16} + \gamma \Delta X_{i,19} + \delta W_{i,16} + \varepsilon_i$ using data on offshore US dollar trading between 2016 and 2019. Robust t-statistics are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Despite the relatively low explanatory power of $\Delta X_{i,19}$, the British pound has a correlation estimate of 0.9862 between $Y_{i,2013}$ and $X_{i,2013}$ and between $Y_{i,2016}$ and $X_{i,2016}$, and 0.9867 between $Y_{i,2019}$ and $X_{i,}2019$; this indicates that the patterns of offshore British pound trading share and total FX trading share across financial centers are quite similar. The results in general are in accordance with the view that the RMB's transition behavior is unique among the SDR currencies.

and does not qualitatively affect other estimates. See Appendix I, Table A1.15.

[41] For completeness, the change in total trading between 2016 and 2019 explains 84% of the variability of offshore euro trading.

Table 1.8 Changes in Shares of Offshore Japanese Yen Trading

Variables	(1)	(2)	(3)	(4)
$Z_{i,16}$	0.096			0.100
	(0.22)			(0.86)
$\Delta X_{i,19}$		1.475***		1.479***
		(12.97)		(17.19)
$W_{i,16}$			-0.001	-0.001
			(0.10)	(0.68)
Constant	-0.000	0.000	0.000	0.000
	(0.01)	(0.28)	(0.27)	(1.29)
Adjusted R^2	-0.02	0.95	-0.02	0.96
Observations	50	50	50	50

Note: The tables present results from estimating $\Delta Y_{i,19} = \alpha + \beta Z_{i,16} + \gamma \Delta X_{i,19} + \delta W_{i,16} + \varepsilon_i$ using data on offshore Japanese yen trading between 2016 and 2019. Robust t-statistics are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table 1.9 Changes in Shares of Offshore British Pound Trading

Variables	(1)	(2)	(3)	(4)
$Z_{i,16}$	-0.023			-0.119***
	(0.77)			(7.05)
$\Delta X_{i,19}$		0.322**		0.506***
		(2.29)		(5.34)
$W_{i,16}$			-0.000	-0.001
			(0.49)	(1.22)
Constant	-0.000	-0.000	0.000	0.000
	(0.36)	(0.31)	(0.07)	(1.06)
Adjusted R^2	-0.01	0.27	-0.02	0.50
Observations	50	50	50	50

Note: The tables present results from estimating $\Delta Y_{i,19} = \alpha + \beta Z_{i,16} + \gamma \Delta X_{i,19} + \delta W_{i,16} + \varepsilon_i$ using data on offshore British pound trading between 2016 and 2019. Robust t-statistics are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

1.4 Empirical Analyses – Euro

In this subsection, I follow Westermann (2023), who examines the evolution pattern of the euro and compares it with that of the RMB. I replicate his dataset for the euro, which is mainly based on BIS data, and reproduce some of his results.

The basic regression follows Cheung et al. (2019) and, unlike the approach for the RMB in sections 1.3.2 and 1.3.3, does not include dispute or trade-related variables. However, the included variables are defined here for the euro in the same way as in Section 1.3.1 for the RMB. Thus, $\Delta Y_{i,t}$ corresponds to the change in euro trade in jurisdiction i from $t-1$ to t, where $t-1$ is the previous BIS triennial survey, so the interval is three years. The independent variables are composed of the constant α, the gap between jurisdiction i's share of offshore euro trading, and its share of all currency trading, $Z_{i,t-1}$ (i.e. the convergence parameter). To this is added the change in jurisdiction i's share of global currency trading ($\Delta X_{i,t}$) between $t-1$ and t, as well as $W_{i,t-1}$, the share of euro turnover in jurisdiction i's total FX turnover in $t-1$.[42]

$$\Delta Y_{i,t} = \alpha + \beta Z_{i,t-1} + \gamma \Delta X_{i,t} + \delta W_{i,t-1} + \varepsilon_i \quad (3)$$

Table 1.10 shows the result of the estimation of (3) for different time periods of t and $t-1$. It can be seen that $\Delta X_{i,t}$ always has a significant positive influence on euro trading. $Z_{i,t-1}$ is significant only in the samples 2001 – 2004 and 2007 – 2010. In these cases, the coefficient is negative and thus there seems to be a convergence of the geographical distribution pattern of euro trading to that of global FX trading at the beginning of the use of the euro and between 2007 and 2010.

In the next step, some control variables are added to the basic regression as previously for the RMB. These are again divided into three groups, links to the euro area ($T_{i,t}$), economic characteristics of financial centers ($U_{i,t}$), and institutional characteristics ($V_{i,t}$).

[42] See Appendix I, Table A1.16 for the definition and data sources of variables of equations (3) and (4).

$$\Delta Y_{i,t} = \alpha + \beta Z_{i,t-1} + \gamma \Delta X_{i,t} + \delta W_{i,t-1} + \mu T_{i,t} + \zeta U_{i,t} + \lambda V_{i,t} + \varepsilon_i \quad (4)$$

First, the results of the equation augmented by the three groups of determinants individually for the period 2016 – 2019 are reported in detail in Tables 1.11, 1.12, and 1.13. Table 1.14 then contains the estimation of (4) for the other periods.

Table 1.10 Changes in Shares of Offshore Euro Trading

Variables	(2001-04)	(2004-07)	(2007-10)	(2010-13)	(2013-16)	(2016-19)
$Z_{i,16}$	-0.144***	-0.026	-0.110**	-0.052	0.062	-0.048
	(4.17)	(0.50)	(2.13)	(0.50)	(0.52)	(1.15)
$\Delta X_{i,19}$	0.886***	1.013***	1.314***	0.985***	0.581**	0.645***
	(11.09)	(9.04)	(7.29)	(5.87)	(2.54)	(8.59)
$W_{i,16}$	-0.002*	0.002	-0.000	-0.001	-0.001	-0.003*
	(1.79)	(0.82)	(0.11)	(0.97)	(1.00)	(1.74)
Constant	0.000	-0.000	0.000	0.000	0.000	0.001
	(1.05)	(0.67)	(0.04)	(0.25)	(0.38)	(1.43)
Adjusted R^2	0.89	0.81	0.79	0.74	0.51	0.86
Observations	34	39	40	40	39	37

Note: The Table presents results on geographical diffusion of offshore euro trading from period t-1 to t (2001 - 2004, 2004 - 2007, 2007 - 2010, 2010 - 2013, 2013 - 2016, and 2016 - 2019. See the text and Table A1.16 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

The links to the euro area include bilateral trade ($BT_{i,t}$), the logged distance to the euro area, the existence of a bilateral swap agreement between the jurisdiction’s central bank and the ECB, and whether a free trade agreement (FTA) exists between the EU and the respective country. Table 1.11 Column (3) shows that the existence of a swap agreement has a significant positive impact on the amount of euro trading in a jurisdiction. The other variables, when added individually, have no statistically significant effect. In Column (5) of Table 1.11, all variables were added simultaneously, and bilateral trade also has a reinforcing effect on euro trading. Here, the adjusted R^2 increases noticeably from 0.86 to 0.91 compared to the baseline regression (Table 1.10, column (2016 – 2019)).

Table 1.11 Changes in Shares of Offshore Euro Trading: Links to Offshore Centers (2016 - 2019)

Variables	(1)	(2)	(3)	(4)	(5)
$Z_{i,16}$	-0.051	-0.048	-0.078*	-0.065	-0.097**
	(1.23)	(1.17)	(1.91)	(1.47)	(2.65)
$\Delta X_{i,19}$	0.641***	0.645***	0.665***	0.663***	0.682***
	(8.07)	(7.92)	(10.94)	(9.00)	(11.26)
$W_{i,16}$	-0.005	-0.003	-0.002	-0.001	-0.005
	(1.33)	(0.94)	(1.38)	(0.87)	(1.48)
$BT_{i,19}$	0.003				0.019**
	(0.61)				(2.16)
Log Distance		-0.000			0.002
		(0.02)			(1.56)
Swap			0.004***		0.005***
			(3.08)		(3.24)
FTA				-0.002	-0.001
				(1.63)	(1.24)
Constant	0.000	0.001	-0.000	0.001*	-0.023
	(0.73)	(0.08)	(0.75)	(1.83)	(1.58)
Adjusted R^2	0.85	0.85	0.90	0.86	0.91
Observations	37	37	37	37	37

Note: The Table presents results on geographical diffusion of offshore euro trading from period t-1 to t (2016 – 2019). See the text and Table A1.16 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table 1.12 shows the result of estimating the baseline regression, augmented with economic characteristics of the respective jurisdiction ($U_{i,t}$). These include GDP growth, equity market capitalization relative to GDP, international bond market capitalization relative to GDP, and the degree of financial development. Added individually, only international bond market capitalization has a statistically significant impact (5% significance level) (see Table 1.12, Column (3)). The negative sign is a bit puzzling but could possibly be explained by the scaling of the variable by GDP. A slower growing bond market relative to GDP could explain the negative sign. [43] Jointly added, none of

[43] Westermann (2023) examined another variant for bond and equity market capitalization, first differences,

the variables has a statistically significant impact, and the adjusted R^2 does not change compared to the baseline regression.

Table 1.12 Changes in Shares of Offshore Euro Trading: Economic Characteristics (2016-2019)

Variables	(1)	(2)	(3)	(4)	(5)
$Z_{i,16}$	-0.047	-0.073	-0.046	-0.047	-0.065
	(1.12)	(1.42)	(1.11)	(1.09)	(1.16)
$\Delta X_{i,19}$	0.644***	0.685***	0.688***	0.644***	0.710***
	(8.47)	(6.82)	(8.35)	(8.32)	(6.98)
$W_{i,16}$	-0.003*	-0.003*	-0.002*	-0.003	-0.002
	(1.82)	(1.92)	(1.96)	(1.68)	(1.09)
GDP Growth	0.000				0.000
	(1.02)				(0.13)
Equity Mkt/GDP		-0.001*			-0.000
		(1.96)			(1.13)
Int. Bond Mkt /GDP			-0.004**		-0.004*
			(2.33)		(1.79)
Financial				0.000	-0.000
Development				(0.54)	(0.45)
Constant	0.001	0.001***	0.002***	0.000	0.002
	(1.43)	(2.83)	(3.24)	(0.36)	(1.69)
Adjusted R^2	0.85	0.87	0.87	0.86	0.86
Observations	37	37	37	37	37

Note: The Table presents results on geographical diffusion of offshore euro trading from period t-1 to t (2016 – 2019). See the text and Table A1.16 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

The final group of control variables, institutional characteristics, is added to the regression in Table 1.13. This group includes a dummy variable that controls for whether jurisdiction i is an Eastern European country, since the German mark was formerly used as a second currency in many of these countries.[44] Other dummy variables control for

but the coefficient was statistically insignificant.

[44] See, for example, Seitz (1995) and Sinn and Westermann (2001).

whether jurisdiction i used to be a colony of a euro country and whether the legal system is based on French or German law. The final dummy variable, which captures financial architecture, equals 1 if a financial center can be classified as bank based and 0 if it is more market based. It is expected that jurisdictions with similar characteristics to the eurozone trade more of this currency. None of these control variables is statistically significant at the 5% significance level.

Table 1.13 Changes in Shares of Offshore Euro Trading: Institutional Characteristics (2016-2019)

Variables	(1)	(2)	(3)	(4)	(5)
$Z_{i,16}$	-0.039	-0.048	-0.039	-0.087	-0.067
	(0.93)	(1.07)	(0.93)	(1.40)	(1.20)
$\Delta X_{i,19}$	0.638***	0.645***	0.637***	0.517***	0.447***
	(8.62)	(7.68)	(8.44)	(5.73)	(5.84)
$W_{i,16}$	-0.006	-0.003*	-0.003**	-0.003	-0.007
	(1.34)	(1.74)	(2.14)	(0.84)	(1.05)
Eastern European	0.002				0.001
	(0.86)				(0.22)
Colony		-0.000			-0.003
		(0.02)			(1.55)
Legal Origin (Fr, Ge)			0.002*		0.003*
			(1.73)		(1.84)
Bank Based				0.000	0.000
				(0.03)	(0.03)
Constant	0.001*	0.001	-0.000	0.000	0.000
	(1.88)	(0.92)	(0.27)	(0.93)	(0.36)
Adjusted R^2	0.86	0.85	0.87	0.76	0.80
Observations	37	37	37	27	27

Note: The Table presents results on geographical diffusion of offshore euro trading from period t-1 to t (2016 – 2019). See the text and Table A1.16 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table 1.14 reports results of the estimation of (4) for all periods. In each case, all control variables were added and the insignificant ones (5% significance level) were gradually eliminated. Despite the addition of control variables, the convergence parameter $Z_{i,t-1}$ remains negative and significant for the periods 2001 – 2004 and 2007 – 2010. It is largest in the first sample, immediately after the introduction of the euro. In addition, it is negative and significant at the 10% level for the 2016 – 2019 sample, but the coefficient itself is substantially smaller.[45] The coefficient for $\Delta X_{i,t}$ is always statistically significant and positive with a fairly large coefficient. The remaining control variables differ greatly in occurrence and sign between the different periods. After stepwise elimination of the insignificant variables, no additional variables to the baseline specification remain in three time periods, 2001 – 2004, 2007 – 2010, and 2013 – 2016. Overall, most variables from the economic characteristics and institutional characteristics groups are statistically significant, but some have a puzzling sign and very small coefficients. From the group of links to the euro area, only in the most recent sample, from 2016 – 2019, does an existing swap line between the respective central bank and the ECB lead to higher euro trading. The number of countries included fluctuates due to on the one hand, the different composition of the euro area and, on the other hand, slight changes in the countries included in the BIS survey.[46]

[45] Westermann (2023) also examines whether the convergence process occurs from above or below. Convergence from above means that in a jurisdiction where the euro was previously overrepresented, the euro offshore euro trading falls.

[46] Westermann (2023) reviews the results with the lowest common number of jurisdictions and reports that the results are robust, except for the period 2010-2013, as here $Z_{i,t-1}$ becomes significant (with a negative sign).

Table 1.14 Changes in Shares of Offshore Euro Trading: Summary

Variables	(2001-04)	(2004-07)	(2007-10)	(2010-13)	(2013-16)	(2016-19)
$Z_{i,t-1}$	-0.144***	-0.064	-0.110**	-0.018	0.063	-0.068*
	(4.17)	(1.37)	(2.15)	(0.41)	(0.53)	(1.99)
$\Delta X_{i,t}$	0.886***	1.116***	1.316***	0.899***	0.582**	0.702***
	(11.09)	(11.51)	(7.31)	(10.43)	(2.53)	(14.57)
$W_{i,t-1}$	-0.002*	0.005*	0.000	-0.007*	-0.001	-0.006**
	(1.79)	(1.82)	(0.01)	(1.82)	(0.75)	(2.32)
Swap						0.005***
						(3.17)
GDP Growth		-0.000**		-0.000***		
		(2.61)		(3.12)		
Equity Mkt/GDP		-0.002***				
		(12.19)				
Int. Bond Mkt /GDP				0.009**		-0.005**
				(2.35)		(2.59)
Eastern European						0.004**
						(2.14)
Colony				-0.007**		
				(2.21)		
Legal Origin (Fr, Ge)				0.005**		
				(2.09)		
Constant	0.000	0.004***	-0.000	-0.001	0.000	0.001***
	(1.05)	(2.89)	(0.05)	(0.98)	(0.44)	(2.87)
Adjusted R^2	0.89	0.93	0.79	0.86	0.50	0.93
Observations	34	36	39	39	37	37

Note: The Table presents results on geographical diffusion of offshore euro trading from period t-1 to t (2001 - 2004, 2004 - 2007, 2007 - 2010, 2010 - 2013, 2013 - 2016, and 2016 - 2019. See the text and Table A1.16 for definitions of variables. Selection of included variables is based on 5% significance level. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

1.5 Concluding Remarks

Most of the analysis just shown is based on joint work with my co-authors, Yin-Wong Cheung and Frank Westermann, and we have analyzed the evolution of RMB trading between 2016 and 2019 against the backdrop of changing global economic and geopolitical environments. In addition to the three FX market variables that are used to evaluate the tendency to narrow the gap between shares of offshore RMB trading and shares of all FX trading, we assess the role of disputes and trade intensity in determining the changes in offshore RMB trading. The results indicate that, under the global conditions between 2016 and 2019, the geographical evolution of offshore RMB trading reflects both the transition toward the pattern of global FX trading and the roles of geopolitics captured by the dispute- and trade-related variables.

In an augmented setting, we added control variables that could influence RMB trading on FX markets. This reveals that while government policies can give a head start to the RMB's internationalization, both economic and geopolitical factors and the responses of incumbent global currencies affect the RMB's path to achieving its global currency stature.

Will the RMB enjoy a global stature commensurate with China's economic strength and its international trade prowess? Undoubtedly, China's economic strength and trade prowess provide strong support for the RMB in the international monetary system. Its ongoing liberalization of financial markets will increase the attractiveness of the RMB to foreign investors. However, in addition to economic and political strength, a global currency's status is affected by credibility and desirability as perceived by foreign investors. China's latest assertive foreign policy posture and territorial disputes with neighboring countries, the confrontation with the U.S. and other countries, and the restructuring of global supply chains can present alternative forces to shape the RMB internationalization experience. Economic and non-economic forces are likely to interact and play their roles in determining the evolution of offshore RMB trading. Nevertheless, market forces will determine the ultimate geographical trading pattern, which is expected to be similar to that of global FX trading.

The analysis of the geographical spread of a currency and its determinants was conducted not only for the RMB but also for the euro. I reproduced some results from Westermann (2023). The baseline setting consists of three FX market-based independent variables; later control variables were added covering the links of the respective offshore centers to the euro area, the economic characteristics of these centers, and their institutional characteristics. It turns out that market forces determine the international role of the euro. A convergence process, albeit to a lesser extent than in the case of the RMB, emerged only relatively soon after the introduction of the euro. This could be because the euro was the successor to established currencies and was therefore widespread from the outset and did not have to develop to the same extent as the RMB, or that there was no true transition.

Overall, the RMB and the euro are currently at very different points in their development. While the euro is the second most widely used currency, the RMB has a much smaller market share and thus greater development potential and the opportunity to strengthen its international role through policy measures. This is also reflected in the fact that, unlike the euro, the change in the ratio of its average daily FX turnover to the global FX turnover is not significant. The international status of a currency has implications for its issuing country's economic well-being; it also represents its sovereignty and global image.

This analysis does not yet include information on the COVID-19 pandemic or Russia's war of aggression against Ukraine. The most recent BIS survey was published in December 2022 and covers data from April 2022. Thus, the COVID-19 pandemic occurred exactly between the two surveys from 2019 and 2022. From Russia as a financial center, in the 2022 survey, no data are reported in the survey, but the ruble is included.

Appendix I

Table A1.1 Definition of Variables and their Sources (Offshore RMB Trading)

Variables	Definition	Source
$Z_{i,16}$	Deviation of jurisdiction i's RMB share from its FX share	BIS Triennial Survey 2016
$\Delta X_{i,19}$	Change in jurisdiction i's FX share between April 2019 and April 2016	BIS Triennial Survey 2019, 2016
$W_{i,16}$	Jurisdiction i's RMB trading as a share of its total FX trading	BIS Triennial Survey 2016
$BT_{i,19}$	Sum of imports from and exports to China as % of the jurisdiction's total trade (April 2018 to March 2019)	Directions of Trade Statistics, IMF
$D_{i,19}$	Binary variable for the presence of a dispute with China: Australia, Japan, Korea, Singapore, United States	WTO, news
RQFII	Binary variable for an approved RQFII arrangement as of March 2019	SAFE, Global Capital China
RQFII Size	Approved RQFII quota amount as of March 2019 (RMB, 10 billions)	SAFE, Global Capital China
Swap	Binary variable for the presence of a bilateral RMB swap line as of March 2019	People's Bank of China
Swap Size	The size of the bilateral RMB swap line (RMB billions)	People's Bank of China
Clearing Bank	Binary variable for the presence of a local RMB clearing bank as of March 2019	People's Bank of China, news, and various press releases
FDI Share	Sum of FDI to and from China as % of the jurisdiction's total FDI flows in 2018	Coordinated Direct Investment Survey, IMF

FTA	Binary variable for the presence of a bilateral free trade agreement between the jurisdiction and China as of March 2019	Ministry of Commerce, China
CFETS	Binary variable for being included in the CFETS currency basket	CFETS
Log_Distance	The geophysical distance (ln(km)) between the jurisdiction's capital and Beijing, China	OpenStreetMap (https://www.distance.to/)
GDP Growth	Log difference of the jurisdiction's GDP between 2016 and 2018	World Development Indicators, World Bank
Equity Mkt/GDP	The capitalization of the jurisdiction's largest equity market as % of GDP in 2018	World Federation of Exchange, NASDAQ
Int. Bond Mkt /GDP	The size of the jurisdiction's foreign bond market as % of GDP in 2018	BIS Debt Securities Database
Financial Development	The Financial Development Index in the Financial Development Report 2018	World Economic Forum

Table A1.2 Descriptive Statistics (Offshore RMB Trading)

Variable	Observations	Mean	Std. Dev.	Min	Max
$\Delta Y_{i,19}$	50	0.00009	0.00899	-0.04925	0.02784
$Z_{i,16}$	50	-0.00031	0.05719	-0.17761	0.31802
$\Delta X_{i,19}$	50	-0.00010	0.01076	-0.02967	0.06448
$W_{i,16}$	50	0.01008	0.02810	0	0.17659
$BT_{i,19}$	50	0.11269	0.09520	0.00955	0.49814

Note: The Table lists some descriptive statistics of, except the dispute dummy variable, the variables included in equation (1).

Table A1.3 Changes in Shares of Offshore RMB Trading: Results from $\Delta BT_{i,19}$

Variables	(1)	(2)	(3)
$Z_{i,16}$	0.005	0.036	-0.183**
	(0.14)	(0.36)	(2.42)
$\Delta X_{i,19}$	0.377***	0.423**	-0.248
	(4.53)	(2.10)	(1.09)
$W_{i,16}$	-0.001	0.040	0.450***
	(0.01)	(0.52)	(2.88)
$\Delta BT_{i,19}$		0.028	-0.043
		(0.55)	(1.39)
$Z_{i,16}*\Delta BT_{i,19}$		5.224	
		(0.30)	
D_i			-0.030**
			(2.55)
$D_i*\Delta BT_{i,19}$)			1.014**
			(2.29)
Constant	0.000	0.000	-0.001
	(0.35)	(0.19)	(1.57)
Adjusted R^2	0.15	0.12	0.60
Observations	50	50	50

Note: The table presents results from estimating $\Delta Y_{i,19} = \alpha + \beta Z_{i,16} + \gamma \Delta X_{i,19} + \delta W_{i,16} + \mu D_i + \zeta \Delta BT_{i,19} + \lambda \Delta BT_{i,19}*D_i + \varepsilon_i$. Robust t-statistics are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table A1.4 Convergence of the RMB Share to Total FX Share

Variables	(1)	(2)	(3)	(4)	(5)
$W_{i,16}$	0.001				0.097**
	(0.01)				(2.28)
$BT_{i,19}$		0.008		0.020	0.001
		(0.54)		(1.65)	(0.07)
D_i			-0.018**	-0.066***	-0.075***
			(2.26)	(4.35)	(4.02)
$BT_{i,19}$*D_i				0.225***	0.265***
				(3.27)	(3.33)
Constant	-0.001	-0.002	0.000	-0.002	-0.000
	(1.25)	(1.13)	(0.35)	(0.98)	(0.21)
Adjusted R^2	-0.02	-0.01	0.25	0.48	0.50
Observations	50	50	50	50	50

Note: The table presents results from estimating $|Z_{i,2019}| - |Z_{i,2016}| = \alpha + \delta W_{i,16} + \mu D_i + \zeta BT_{i,19} + \lambda BT_{i,19} * D_i + \varepsilon_i$. Robust t-statistics are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table A1.5 Convergence of the RMB Share to Total FX Share: A Synthetic Formulation

Variables	(1)	(2)	(3)	(4)	(5)
$W_{i,16}$	0.097**	-0.304	0.102	0.094**	-0.318
	(2.28)	(1.29)	(1.06)	(2.48)	(1.37)
D_i	-0.075***	-0.059***	-0.075***	-0.076***	-0.061***
	(4.02)	(4.82)	(3.99)	(3.96)	(5.19)
$BT_{i,19}$	0.001	0.003	0.001	0.001	0.016*
	(0.07)	(0.38)	(0.11)	(0.07)	(1.98)
$BT_{i,19}*D_i$	0.265***	0.204***	0.265***	0.265***	0.186***
	(3.33)	(3.46)	(3.29)	(3.30)	(3.10)
RQFII size		0.002			0.004
		(1.58)			(1.66)
Equity mkt			-0.000		-0.006
			(0.08)		(1.32)
Financial				-0.001	-0.006
Development				(0.28)	(0.87)
Constant	-0.000	-0.000	-0.000	0.000	0.004
	(0.21)	(0.01)	(0.18)	(0.03)	(0.73)
Adjusted R^2	0.50	0.57	0.49	0.49	0.61
Observations	50	50	50	50	50

Note: The table presents results from estimating $|Z_{i,2019}| - |Z_{i,2016}| = \alpha + \delta W_{i,16} + \mu D_i + \zeta BT_{i,19} + \lambda BT_{i,19}*D_i + \tau Q_i + \varepsilon_i$. Robust t-statistics are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table A1.6 Changes in Shares of Offshore RMB Trading: Alternative Sample Periods, FX Market Variables

Variables	2013-2016 Sample	2016-2019 Sample	Pooled Sample
Z_i	-0.222***	0.005	-0.064
	(4.25)	(0.14)	(1.37)
ΔX_i	1.507***	0.377***	0.353**
	(5.40)	(4.53)	(2.26)
W_i	0.004	-0.001	-0.014
	(0.06)	(0.01)	(0.09)
Constant	-0.000	0.000	0.000
	(0.10)	(0.35)	(0.30)
Adjusted R^2	0.85	0.15	0.22
Observations	50	50	100

Notes: The table presents results from estimating $\Delta Y_{i,t} = \alpha + \beta Z_{i,t-1} + \gamma \Delta X_{i,t} + \delta W_{i,t-1} + \varepsilon_i$ for the 2013-16 sample, the 2016-19 sample, and the pooled sample. OLS estimates. Robust t-statistics in parentheses; *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively. The Chow test statistic for testing the null hypothesis of there is no structural break between the 2013 - 2016 and 2016 - 2019 specifications is 17.5.

Table A1.7 Changes in Shares of Offshore RMB Trading: Alternative Sample Periods

Variables	2013-2016 Sample	2016-2019 Sample	Pooled Sample
Z_i	-0.138*	-0.175***	-0.059
	(1.87)	(2.90)	(1.35)
ΔX_i	1.021**	-0.244	0.372**
	(2.47)	(1.29)	(2.37)
W_i	-0.135	0.423***	-0.068
	(1.34)	(3.26)	(0.41)
D_i	0.024	-0.079***	-0.003
	(1.47)	(3.73)	(0.11)
$BT_{i,19}$	0.006	0.008	0.019
	(1.67)	(1.23)	(1.58)
D_i*$BT_{i,19}$	-0.069	0.240***	0.021
	(0.94)	(3.29)	(0.19)
Constant	-0.001	-0.002**	-0.002
	(1.11)	(2.16)	(1.22)
Adjusted R^2	0.89	0.70	0.23
Observations	50	50	100

Note: The Tables present results from estimating $\Delta Y_{i,19} = \alpha + \beta Z_{i,16} + \gamma \Delta X_{i,19} + \delta W_{i,16} + \mu D_i + \zeta BT_{i,19} + \lambda BT_{i,19}*D_i + \varepsilon_i$ for the 2013-16 sample, the 2016-19 sample, and the pooled sample. The robust t-statistics are in parentheses, and *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively. The Chow test statistic for testing the null hypothesis of there is no structural break between the 2013-2016 and 2016-19 specifications is 40.9.

Table A1.8 Changes in Shares of Offshore RMB Trading: China's Policies, Standardized by GDP

Variables	(1)	(2)	(3)	(4)	(5)	(P)
$Z_{i,16}$	-0.196***	-0.170***	-0.176***	-0.175***	-0.184***	-0.170***
	(3.05)	(5.22)	(2.97)	(2.88)	(3.01)	(5.22)
$\Delta X_{i,19}$	-0.265	-0.128	-0.242	-0.245	-0.248	-0.128
	(1.41)	(1.15)	(1.30)	(1.28)	(1.33)	(1.15)
$W_{i,16}$	0.489***	0.101	0.435***	0.423***	0.448***	0.101
	(3.37)	(0.76)	(3.36)	(3.24)	(3.43)	(0.76)
D_i	-0.081***	-0.054***	-0.080***	-0.079***	-0.079***	-0.054***
	(4.05)	(3.80)	(3.76)	(3.70)	(3.87)	(3.80)
$BT_{i,19}$	0.005	0.007	0.006	0.009	0.009	0.007
	(1.01)	(1.41)	(0.76)	(1.23)	(1.22)	(1.41)
$BT_{i,19}*D_i$	0.250***	0.177***	0.247***	0.240***	0.241***	0.177***
	(3.63)	(3.28)	(3.34)	(3.26)	(3.44)	(3.28)
RQFII	-0.003					
	(1.00)					
RQFII Size		0.042***				0.042***
		(2.85)				(2.85)
Swap			-0.001			
			(0.76)			
Swap Size				0.123		
				(0.75)		
Clearing Bank					-0.002	
					(0.96)	
Constant	-0.002**	-0.002*	-0.002	-0.002**	-0.002**	-0.002*
	(2.24)	(1.79)	(1.28)	(2.06)	(2.26)	(1.79)
Adjusted R^2	0.71	0.83	0.69	0.69	0.70	0.83
Observations	50	50	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. RQFII Size and Swap Size are standardized by GDP. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table A1.9 Changes in Shares of Offshore RMB Trading: China's Policies, Additional Interaction: D*Q

Variables	(1)	(2)	(3)	(4)	(5)
$Z_{i,16}$	-0.185***	-0.134***	-0.094	0.024	-0.177***
	(2.73)	(4.10)	(1.41)	(0.69)	(2.72)
$\Delta X_{i,19}$	-0.247	-0.147	0.015	0.389***	-0.237
	(1.22)	(1.29)	(0.07)	(3.25)	(1.17)
$W_{i,16}$	0.475***	-0.047	0.279**	0.098	0.449***
	(3.29)	(0.65)	(2.38)	(1.36)	(3.39)
$BT_{i,19}$	0.003	0.006	0.006	-0.005	0.005
	(0.60)	(1.56)	(0.67)	(1.60)	(0.72)
D_i	-0.083***	-0.046***	-0.088***	-0.017	-0.082***
	(4.39)	(3.44)	(4.18)	(1.65)	(4.26)
$BT_{i,19}*D_i$	0.247***	0.157***	0.298***	0.159***	0.241***
	(3.89)	(3.23)	(3.29)	(5.62)	(3.76)
RQFII	-0.002				
	(0.59)				
RQFII*D_i	0.013**				
	(2.55)				
RQFII Size		0.002***			
		(6.44)			
RQFII Size*D_i		-0.002*			
		(1.71)			
Swap			0.000		
			(0.12)		
Swap*D_i			0.025		
			(1.66)		
Swap Size				-0.003**	
				(2.31)	
Swap Size*D_i				-1.399***	
				(9.41)	
Clearing Bank					-0.001
					(0.46)
Clearing Bank*D_i					0.014***
					(2.77)
Constant	-0.002**	-0.001	-0.001	0.001*	-0.002**
	(2.05)	(1.67)	(0.91)	(1.70)	(2.05)
Adjusted R^2	0.74	0.88	0.75	0.93	0.73
Observations	50	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table A1.10 Changes in Shares of Offshore RMB Trading: Links to China, Additional Interaction: D*Q

Variables	(1)	(2)	(3)	(4)	(5)
$Z_{i,16}$	-0.170***	-0.072	-0.172***	-0.176***	-0.133**
	(2.85)	(1.59)	(2.77)	(2.83)	(2.18)
$\Delta X_{i,19}$	-0.222	0.095	-0.236	-0.250	-0.091
	(1.18)	(0.67)	(1.21)	(1.28)	(0.50)
$W_{i,16}$	0.381***	0.281***	0.409***	0.424***	0.376***
	(2.80)	(3.05)	(3.02)	(3.09)	(3.14)
$BT_{i,19}$	0.006	-0.004	0.011	0.009	0.001
	(0.98)	(0.33)	(1.49)	(1.00)	(0.28)
D_i	-0.075***	-0.097***	-0.078***	-0.071**	-0.077***
	(3.72)	(8.70)	(3.60)	(2.22)	(4.00)
$BT_{i,19}*D_i$	0.226***	0.314***	0.235***	0.239***	0.198**
	(3.36)	(7.47)	(3.15)	(3.27)	(2.39)
FDI Share	0.020				
	(1.00)				
FDI Share*D_i	0.007				
	(0.15)				
FTA		0.000			
		(0.07)			
FTA*D_i		0.031***			
		(3.47)			
CFETS			0.001		
			(0.60)		
Log_Distance				0.007	
				(0.05)	
Log_Distance *D_i				-0.090	
				(0.29)	
Belt & Road					-0.000
					(0.06)
Belt & Road*D_i					0.017
					(1.65)
Constant	-0.002**	-0.000	-0.003*	-0.003	-0.001
	(2.17)	(0.33)	(2.01)	(0.24)	(0.84)
Adjusted R^2	0.70	0.86	0.69	0.69	0.75
Observations	50	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table A1.11 Changes in Shares of Offshore RMB Trading: Characteristics of Jurisdictions, Additional Interaction: D*Q

Variables	(1)	(2)	(3)	(4)
$Z_{i,16}$	-0.136**	-0.004	-0.066	-0.174***
	(2.47)	(0.19)	(1.34)	(2.78)
$\Delta X_{i,19}$	-0.111	0.299***	0.076	-0.228
	(0.64)	(4.21)	(0.47)	(1.20)
$W_{i,16}$	0.387***	-0.076	0.231**	0.431***
	(3.48)	(0.96)	(2.40)	(3.19)
$BT_{i,19}$	0.000	-0.003	0.005	0.007
	(0.03)	(0.93)	(0.82)	(1.01)
D_i	-0.069***	0.070***	-0.049***	-0.082***
	(4.70)	(4.88)	(4.14)	(3.64)
$BT_{i,19}*D_i$	0.306***	-0.064**	0.234***	0.282***
	(5.05)	(2.19)	(4.83)	(2.77)
GDP Growth	-0.001			
	(1.10)			
GDP Growth*D_i	-0.260***			
	(3.50)			
Equity Mkt/GDP		0.004***		
		(3.39)		
Equity Mkt/GDP*D_i		-0.057***		
		(9.50)		
Int. Bond Mkt /GDP			0.005	
			(0.34)	
Int. Bond Mkt /GDP*D_i			-7.671***	
			(3.62)	
Financial Development				0.001
				(0.48)
Financial Development*D_i				-0.053
				(0.87)
Constant	-0.001	-0.001**	-0.001	-0.003
	(1.35)	(2.35)	(0.92)	(1.38)
Adjusted R^2	0.79	0.94	0.83	0.69
Observations	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table A1.12 Changes in Shares of Offshore RMB Trading: China's Policies, Additional Interaction: BT*Q

Variables	(1)	(2)	(3)	(4)	(5)
$Z_{i,16}$	-0.187***	-0.168***	-0.175***	-0.180***	-0.188***
	(3.29)	(11.12)	(2.91)	(3.35)	(3.32)
$\Delta X_{i,19}$	-0.208	-0.021	-0.235	-0.235	-0.237
	(1.27)	(0.29)	(1.25)	(1.40)	(1.40)
$W_{i,16}$	0.359**	-0.015	0.419***	0.443***	0.415***
	(2.13)	(0.30)	(3.07)	(3.74)	(3.44)
$BT_{i,19}$	0.002	-0.000	0.002	0.015*	0.000
	(0.39)	(0.13)	(0.51)	(1.75)	(0.04)
D_i	-0.065***	-0.034***	-0.078***	-0.080***	-0.073***
	(3.22)	(3.82)	(3.51)	(4.17)	(3.82)
D_i *$BT_{i,19}$	0.176**	0.106***	0.237***	0.249***	0.213***
	(2.07)	(2.75)	(2.99)	(3.70)	(3.09)
RQFII	-0.007				
	(1.66)				
RQFII*$BT_{i,19}$	0.051				
	(1.14)				
RQFII Size		-0.001**			
		(2.69)			
RQFII Size*$BT_{i,19}$		0.008***			
		(6.46)			
Swap			-0.002		
			(1.16)		
Swap*$BT_{i,19}$			0.009		
			(0.46)		
Swap Size				0.028**	
				(2.05)	
Swap Size*$BT_{i,19}$				-0.751*	
				(1.88)	
Clearing Bank					-0.005
					(1.50)
Clearing Bank*$BT_{i,19}$					0.029
					(1.18)
Constant	-0.001	-0.000	-0.001	-0.003**	-0.001
	(1.63)	(0.23)	(1.35)	(2.24)	(1.41)
Adjusted R^2	0.72	0.93	0.69	0.72	0.71
Observations	50	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table A1.13 Changes in Shares of Offshore RMB Trading: Links to China, Additional Interaction: BT*Q

Variables	(1)	(2)	(3)	(4)	(5)
$Z_{i,16}$	-0.154***	-0.165***	-0.170***	-0.131***	-0.171**
	(12.76)	(3.37)	(2.94)	(3.69)	(2.62)
$\Delta X_{i,19}$	-0.026	-0.190	-0.216	-0.057	-0.240
	(0.47)	(1.27)	(1.20)	(0.49)	(1.19)
$W_{i,16}$	-0.089*	0.384***	0.360***	0.077	0.425***
	(1.69)	(3.30)	(2.83)	(0.77)	(2.99)
$BT_{i,19}$	-0.005**	0.017	-0.010	0.907***	0.011
	(2.16)	(1.27)	(1.22)	(4.85)	(0.95)
D_i	-0.033***	-0.072***	-0.072***	-0.049***	-0.078***
	(5.99)	(3.37)	(3.60)	(4.90)	(3.55)
D_i *$BT_{i,19}$	0.099***	0.218***	0.204***	0.141***	0.237***
	(4.61)	(2.77)	(2.89)	(4.28)	(3.12)
FDI Share	-0.099***				
	(11.56)				
FDI Share*$BT_{i,19}$	0.726***				
	(15.00)				
FTA		-0.008			
		(0.66)			
FTA*$BT_{i,19}$		0.018			
		(0.33)			
CFETS			-0.004**		
			(2.38)		
CFETS*$BT_{i,19}$			0.041**		
			(2.18)		
Log_Distance				0.017***	
				(4.22)	
Log_Distance *$BT_{i,19}$				-0.099***	
				(4.77)	
Belt & Road					-0.000
					(0.22)
Belt & Road*$BT_{i,19}$					-0.005
					(0.42)
Constant	0.001	-0.002**	0.000	-0.157***	-0.002
	(1.16)	(2.27)	(0.11)	(4.28)	(0.95)
Adjusted R^2	0.94	0.72	0.71	0.83	0.69
Observations	50	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table A1.14 Changes in Shares of Offshore RMB Trading: Characteristics of Jurisdictions, Additional Interaction: BT*Q

Variables	(1)	(2)	(3)	(4)
$Z_{i,16}$	-0.177***	-0.164***	-0.177***	-0.178***
	(2.98)	(7.22)	(3.72)	(3.41)
$\Delta X_{i,19}$	-0.242	-0.072	-0.228	-0.213
	(1.30)	(0.96)	(1.51)	(1.35)
$W_{i,16}$	0.426***	-0.006	0.268**	0.336***
	(3.34)	(0.06)	(2.23)	(2.83)
$BT_{i,19}$	0.022	-0.010***	-0.012	0.054**
	(1.33)	(3.82)	(1.38)	(2.54)
D_i	-0.080***	-0.045***	-0.063***	-0.069***
	(3.90)	(4.41)	(3.29)	(4.02)
D_i*$BT_{i,19}$	0.249***	0.151***	0.185**	0.192***
	(3.49)	(3.23)	(2.55)	(3.09)
GDP Growth	0.016			
	(1.13)			
GDP Growth $BT_{i,19}$	-0.182			
	(1.33)			
Equity Mkt/GDP		-0.001		
		(0.24)		
Equity Mkt/GDP*$BT_{i,19}$		0.018***		
		(4.13)		
Int. Bond Mkt /GDP			-0.000**	
			(2.63)	
Int. Bond Mkt /GDP*$BT_{i,19}$			0.001**	
			(2.56)	
Financial Development				0.009**
				(2.67)
Financial Development*$BT_{i,19}$				-0.111***
				(2.81)
Constant	-0.004*	-0.000	-0.001	-0.006**
	(1.79)	(0.30)	(0.83)	(2.63)
Adjusted R^2	0.70	0.91	0.76	0.74
Observations	50	50	50	50

Note: The Table presents results on geographical diffusion of offshore RMB trading between 2016 and 2019. See the text and Table A1.1 for definitions of variables. OLS estimates and their robust t-statistics (in parentheses) are reported. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level respectively.

Table A1.15 Changes in Shares of Offshore (SDR) Trading

Variables	(USD)	(JPY)	(GBP)
$Z_{i,16}$	-0.113	0.099	-0.122***
	(1.32)	(0.84)	(6.62)
$\Delta X_{i,19}$	1.027***	1.477***	0.513***
	(79.87)	(16.96)	(5.46)
$W_{i,16}$	-0.001**	-0.001	-0.001*
	(2.19)	(0.61)	(1.77)
$BT_{i,19}$	-0.000	-0.009	0.018
	(0.03)	(0.93)	(1.36)
Constant	0.000**	0.001*	0.000
	(2.59)	(1.69)	(0.37)
R-Squared (adj)	1.00	0.96	0.51
Observations	50	50	50

Notes: The table presents results from estimating $\Delta Y_{i,19} = \alpha + \beta Z_{i,16} + \gamma \Delta X_{i,19} + \delta W_{i,16} + \varepsilon_i$ for the 2016-19 sample for the US dollar (USD), the Japanese yen (JPY), and the British pound (GBP). OLS estimates. Robust t-statistics in parentheses; *, **, *** indicate variables significant at 10%, 5%, and 1% level respectively.

Table A1.16 Definition of Variables and their Sources (EUR)

Variables	Definition	Source
$Z_{i,t-1}$	Deviation of jurisdiction i's EUR share from its FX share	BIS Triennial Survey 1995-2019
$\Delta X_{i,t}$	Change in jurisdiction i's FX share between April in year t and April t-1	BIS Triennial Survey 1995-2019
$W_{i,t-1}$	Jurisdiction i's EUR trading as a share of its total FX trading	BIS Triennial Survey 1995-2019
$BT_{i,t}$	Sum of imports from and exports to the Euro Area as % of the jurisdiction's total trade (April to March in t)	Directions of Trade Statistics, IMF
Swap	Binary variable for the presence of a bilateral EUR swap line with the ECB as of March 2019	European Central Bank
FTA	Binary variable for the presence of a bilateral free trade agreement between the jurisdiction and the EU as of March t	European Commission
Log_Distance	The geophysical distance (ln(km)) between the jurisdiction's capital and Frankfurt, Germany	OpenStreetMap (https://www.distance.to/)
GDP Growth	Log difference of the jurisdiction's GDP between t-1 and t	World Development Indicators, World Bank
Equity Mkt/GDP	The capitalization of the jurisdiction's largest equity market as % of GDP	World Federation of Exchange, NASDAQ
Int. Bond Mkt /GDP	The size of the jurisdiction's foreign bond market as % of GDP	BIS Debt Securities Database
Financial Development	The Financial Development Index in the Financial Development Report	World Economic Forum
Eastern European	Binary variable for an Eastern European Country or Sweden which is member of the EU but does not have	European Union

	the Euro (Bulgaria, Czech Republic, Hungary, Poland, Romania, Sweden)	
Colony	Binary variable for a former colony of Euro Area countries, 1812-WW1	Bundeszentrale für Politische Bildung
Legal Origin (Fr, Ge)	Binary variable for a legal system originating from French or German law	Beck et al. 2002, La Porta et al. 1998
Bank Based	Binary variable for the lowest quartile of the ratio of stock market capitalization to bank credit (both as percentage of GDP)	Beck et al. 2010

2 Exchange Rate Regime Choice

2.1 Motivation

There is renewed interest in the topic of optimal currency areas for various reasons: first, twenty years after the introduction of the euro, the monetary union keeps expanding. Croatia adopted the euro in January 2023, Bulgaria participates in the Exchange Rate Mechanism (ERM) II, and Romania prepares for the next steps to introduce the euro. Second, the Chinese RMB is gradually taking center stage as an anchor currency for East and Southeast Asian countries, for several reasons. During the Asian crisis in 1997/8, many East Asian countries unpegged their currencies from the U.S. dollar and are now working toward greater economic integration within the region. For example, institutions for policy coordination, such as Association of Southeast Asian Nations Plus Three (ASEAN+3) and the Chiang Mai Initiative (CMI), have been introduced. Furthermore, China has begun to actively promote the spread of the RMB in international markets and has introduced clearing banks in foreign countries, swap line agreements, and investment quotas. The RMB now plays a major role in international financial markets, ranking fourth among the most widely used currencies (according to SWIFT). A further reason for tighter monetary cooperation is increased trade integration. Bilateral trade with China accounts for more than a quarter of the trade for Hong Kong, Taiwan, Macau, and Korea. Finally, the Belt and Road Initiative aims to enhance trade even further. A third reason for broad interest in optimal currency areas and optimal exchange rate regime choice is the recent announcement by the presidents of Brazil and Argentina that they were considering adopting a common currency, el sur, which drew a lively debate among economists.

In a recent empirical assessment of potentially acceding countries to the eurozone, Deskar-Škrbić et al. (2021) argue that the candidate countries are indeed ready to join the common currency, using an advanced version of the classical empirical method initially proposed by Bayoumi and Eichengreen's classical 1993 article,[47] whose basic idea was to take a trend-cycle decomposition and analyze the correlation of short-term shocks, which are interpreted as demand shock. The intuition for this approach follows from

[47] This adds to the older meta-study by Fidrmuc and Korhonen (2006), indicating that central and eastern European countries exhibit a comparably high correlation with the euro area business cycle.

Mundell's (1961) work on optimum currency areas, and it has more recently been formally illustrated by Berger et al. (2001). However, it is only the *contemporaneous* correlation that is considered, not the potential spillover of the shock to the next period, the one thereafter, and so on. The shocks are essentially assumed to be white noise processes, without any autoregressive element.

In a parallel strand of the literature started by Beine, Candelon, and Hecq (2000) and summarized in De Haan et al. (2008), the dynamics of exogenous shocks are exactly in the focus of the analysis. They use the serial correlation common feature test, initially developed by Engle and Kozicki (1993) and later extended by Vahid and Engle (1993, 1997), to analyze whether the impulse response patterns to external shocks are similar across countries. Like the initial paper by Bayoumi and Eichengreen (1993), their assessment is rather negative, and they ultimately reach the same conclusion on the set of countries that have started the EMU in the year 1999.

The common features test has also been applied to the East Asian region to analyze the suitability of fixed exchange rate arrangements. Cheung and Yuen (2005) have analyzed China, Hong Kong, and Taiwan in terms of a Greater China currency union and found that the three countries indeed share common long- and short-run cyclical variations. Sato and Zhang (2006) have assessed the suitability of a monetary union in East Asia for nine Asian countries and found that a monetary union with China would be feasible for both Hong Kong and Korea. Both studies are based on seasonally adjusted data. However, complex serial correlation patterns, as well as both deterministic and stochastic seasonality, are key features of macroeconomic data. Hecq (1998), Cubadda (1999), and Hecq et al. (2017) argue that the seasonal adjustment of data can spuriously affect the codependence properties of time series.

The contribution to this literature is twofold. First, we document formally, following the theoretical setup of Berger et al. (2001), that a common persistence of shocks – and not only their contemporaneous correlation – is a necessary precondition for minimizing the costs associated with adopting a common currency. Postulating this new criterion, we provide an extension of Mundel's (1961) analytical framework and document that the studies relying on the serial correlation common feature test are indeed applying an appropriate testing procedure.[48] Second, for the euro area accession candidates, as well as for countries that could enter into closer monetary cooperation with China, we show that estimates from the existing literature may have been overly optimistic in a longer and more recent sample.

For the euro accession candidates, this relates to the article by Deskar-Škrbić et al. (2021). For the potential new member countries, just as the earlier literature has documented for the first 12 euro countries (EA12), little evidence exists of a common impulse response pattern after an initial shock. I cannot confirm such evidence using seasonalized data for East Asian countries in a long an recent sample either, in contrast to Cheung and Yuen (2005) and Sato and Zang (2006).

In developing our conceptual framework, we take a simple version of the Barro-Gordon (1983) model, where, in the absence of persistence, the optimal regime choice depends on the correlation of domestic and foreign shocks – the typical criterion used in the earlier empirical literature. We add the feature that the common shocks can be autocorrelated and derive some additional results. First, we highlight that an additional inflation bias exists that is independent of the well-known time-inconsistency bias. It can be positive or negative, depending on the relative persistence of the home and domestic shocks. The overall welfare, in an unconditional equilibrium, however, does not depend on the autocorrelation under flexible exchange rates.

The main findings concerning the persistence of shock are driven in the fixed exchange rate/monetary union case. We show in the model section that there exists an additional welfare loss from joining a monetary union – either for the existing union or for the joining country – if the persistence of shocks differs between the domestic and the foreign shock. The welfare loss is zero if, and only if, the persistence is identical. The implication is that in a symmetric equilibrium, a common persistence of shocks is indeed a new criterion for an optimum currency area.[49]

[48] For instance, Beine et al. (2000), Candelon et al. (2005), Hecq et al. (2006), Sato and Zhang (2006), Cubadda et al. (2013), and Trenkler and Weber (2020).
[49] The problem of diverging effects to otherwise common shocks in currency areas has also been noted in the influential “One Money, One Market” report by the European Commission (1990).

An autoregressive process of order one, which we use to illustrate our point in the model, of course, does not fully capture the empirical autocorrelation functions observed in practice. Most quarterly GDP time series are autoregressive processes of orders between four to eight periods, often with alternating positive and negative autoregressive coefficients, which are responsible for a hump-shaped cumulative impulse response pattern. Therefore, we document that for higher-order autoregressive processes, a common set of AR parameters is needed. This similarity of autoregressive parameters is in the focus of the serial correlation common feature test of Beine et al. (2000) and others. The common serial correlation feature indeed ensures that the additional welfare loss from joining the monetary union is zero. Our model can be viewed as the theoretical underpinning of this testing approach, which is highly relevant to the OCA literature.

To evaluate the suitability of acceding countries to join the European Monetary Union or enhance monetary cooperation with China, we take the model to the data by estimating bivariate SCCF tests. For the euro area, we examine the euro area aggregate in conjunction with all potential candidates individually (i.e., Bulgaria, the Czech Republic, Croatia, Hungary, Poland, Romania, and Sweden). For the East Asian region, 10 East and Southeast Asian countries are examined, each in a bivariate setting with China.

The first part of the analysis includes the visual inspection of seasonal GDP growth rates, autocorrelograms, and correlation coefficients, which provide a first impression of the relationships between the EA12 and the acceding countries and China and East Asian countries, respectively. For Europe, eyeballing the autocorrelation functions of each country compared to that of the EA12 countries provides a first impression of similarities and differences. While some countries have unique patterns, others look quite similar, so a more formal test is warranted. For China, these preliminary analyses foreshadow the results, as they reveal only very few similarities. A more formal analysis begins with a seasonal unit root test (Hylleberg et al., 1990) and a seasonal cointegration test, by Cubadda (1999) and Lee (1992). Afterward, we estimate two versions of the SCCF test based on Cubadda (2001), who proposed an integrated approach of estimating common serial correlation, common trends, and seasonality. The tests are conducted using a two-stage least squares (2SLS) and a generalized method of moments (GMM) estimator. The robustness of the results is verified using the older Tiao and Tsay (1989) test. Further robustness tests include an analysis of the optimal lag choice and an comparison to results from actual euro area countries for European setting and a further examination of the usage of non-deseasonalized data and the COVID-19 pandemic for Asia.

To anticipate results, overall, the evidence for common cyclical response patterns to exogenous shocks of acceding countries to the EA and the EA aggregate is very limited when considering the strict form of the SCCF test, which implies perfect collinearity between the impulse response patterns. Among the countries analyzed, Sweden comes closest to forming an optimal currency area with the current EMU countries. Using the Cubadda (2001) approach, we indeed cannot reject the null hypothesis of a common cycle in our benchmark regression. One should be cautious about this finding, however; as in the Tiao and Tsay (1989) robustness test, we fail to reject the null in even Sweden's case.

For Croatia, Hungary, and the Czech Republic, we do find common cyclical elements when considering the less strict version of the codependence, which allows for an initially asymmetric response in the first quarter but the common reaction thereafter. Together with the EA12, they form a codependent cycle of order one, for at least one of the estimators used – 2SLS or GMM. Finally, all countries show some higher-order codependence of orders two or three, which, however, is hardly relevant in practice, given the overall short-lived cyclical nature of GDP shocks in quarterly data. Overall, while we do not challenge the existence of largely common shocks during the past 20 years, as reported in Deskar-Škrbić et al. (2021), the analysis of asymmetric response patterns leads to a much more conservative assessment about the readiness of countries, and the possible size of a welfare loss, when joining the monetary union.

For East Asia, the examination of common cyclical response patterns to exogenous shocks of individual countries with China also exhibits very limited evidence for it. The strict form of common cycles, a codependence of order zero, would imply perfect collinearity between the impulse response patterns but cannot be found in this dataset. The same is true for a less strict form of codependence, which allows for an asymmetric response in the first quarter. In examining the codependence of orders two or three, Korea, Taiwan, and Hong Kong seem to share common cyclical elements with China. However, we will show that only the strict form of codependence is relevant for a currency union.

The structure of this article is as follows: Section 2.2 provides an overview of the theory of optimal currency areas and criteria developed therein. In Section 2.3, we present our conceptual model framework. Section 2.4 illustrates how our main findings generalize to higher-order AR-processes and lead to the common serial correlation features test. Section 2.5 provides the empirical examination of the acceding countries to the euro area as well as an institutional background. Section 2.6 focuses on China and the RMB as an possible anchor currency and first sheds light on the institutional background which is followed by the empirical assessment of the bivariate analysis with China. Section 2.7 draws some conclusions.[50]

[50] Parts of this section are based on Grimm et al. (2021) including the conceptual framework, the transition to the empirical test, and the empirical analysis of the eurozone accession candidates. I have extended these by including an institutional analysis and the analysis of eurozone members. The analysis of East Asian countries and China is an extended version of Grimm (2022).

2.2 Theory on Optimum Currency Areas

The origins of the theory on optimal currency areas lie in the literature on optimal exchange rate systems. This discussion was stimulated by the difficulties of reintroducing the gold standard after World War I and received a second wave of attention with the plans for a common European currency.[51]

Robert Mundell was the first to use the term "optimum currency areas" in his influential 1961 paper. He considered the possible failure of the proper adjustment through flexible exchange rates and focused on re-establishing equilibrium between countries. For that, he developed criteria under which the loss of flexibility through fixed exchange rates could be less costly, focusing on the trade-off between inflation and unemployment.[52] Mundell describes a situation where demand for goods produced in one country shifts to goods produced in another country. With sticky wages and prices in the short run, this leads to unemployment in the first country and inflationary pressure in the second country. If these two countries' currencies were connected through a flexible exchange rate, the problems of unemployment and inflation could be mitigated through an adjustment of the exchange rate.[53] He also raises the question of the size and area of an optimal currency area. Two other influential papers were written by McKinnon (1963) and Kenen (1969), who developed Mundell's approach further. In addition, many other criteria have been developed, the consideration of which should avoid costs associated with the formation of areas with a common currency (or fixed exchange rates). The criteria are often interrelated or mutually dependent.

In the following decades, the approaches were further developed and, for example, extended by the inclusion of expectations formations and time inconsistency. In addition to the consideration of fixed and flexible exchange rates, unified monetary and fiscal policies also came to the fore. The focus shifts from the development of new

[51] For an early overview over different strands of the literature, see Ishiyama (1975).
[52] In the 1960s, several authors concentrated on differences in the tolerance of unemployment and inflation of the various economies and a trade-off between these two factors. For example, Ishiyama (1975) and Tower and Willett (1976) provide literature surveys.
[53] Mundell (1961) describes a similar situation with two specialized regions within a country. In this case, adjustment cannot occur via an exchange rate.

criteria to empirical approaches.[54]

The formation of a fixed exchange rate system or even a monetary union involves various benefits but also costs, which are often difficult to quantify and weigh. Some advantages of an optimal currency area are obvious: the usefulness of money as a medium of exchange increases with the size of the currency area, prices become more transparent, and exchange rate risk disappears. With flexible exchange rates, transaction costs generally increase with the number of currencies and the volume of trade between countries. These costs, including information, search, and calculation costs, as well as losses due to currency conversions and uncertainty, are reduced by fixed exchange rate systems or a common currency. Thus, a common currency supports integration as well as trade and investment and contributes to efficient allocation (Mundell, 1961; Willett and Tower, 1970; Ishiyama, 1975; Mongelli, 2005).

Conversely, when a fixed exchange rate system is introduced or a monetary union is established, the flexible exchange rate is lost as an important adjustment mechanism between the participating countries. In a currency union, a supranational central bank conducts a common monetary policy for the individual countries. This should represent the interests of all participating countries but is limited to a one-size-fits-all policy that does not suit every economy, especially in the case of asymmetric shocks (Ishiyama, 1975; Tavlas, 1993; Krugman, 2012).

Other costs may arise at the political and institutional levels. When a common currency is introduced, costs arise from the change of currency and the establishment of sub-national institutions (Mongelli, 2005). Willett and Tower (1970) argue that the question of forming a currency area is ultimately a political question and that costs at the political level arise from constraining policymakers in their decisions about the independent use of policy instruments.

The formation or entry into a currency area and the pegging of exchange rates are accompanied by the loss of the adjustment mechanism of a flexible exchange rate. An appreciation or depreciation of a country’s currency to avoid unemployment and

[54] For a survey on these strands of the literature, see De Grauwe (1992) and Tavlas (1993).

inflationary pressures, for example, is no longer possible after an asymmetric shock (Mundell, 1961). In the literature, many criteria have been developed to analyze under which circumstances the loss of the flexible exchange rate is less costly. The more criteria are met, the less the exchange rate is needed as an adjustment mechanism, and the countries would form an optimal currency area.

Mundell (1961)[55] states that *factor mobility* is key to overcoming the problem of inflationary pressure and unemployment. He follows the assumption from Ricardo (1817) that factors being internally mobile do not fulfill this characteristic internationally but concludes that if *capital and labor mobility* was true also internationally, flexible exchange rates between two currencies would no longer be needed and these countries would be suitable to form a currency union. According to Fleming (1971), it is important to distinguish between labor and capital mobility. He questions whether labor mobility can be sufficiently large, even without institutional restrictions, as countries probably have different technologies and labor mobility will be further dampened through different cultural backgrounds and languages. Kenen (1969) adds that different labor intensities in production methods and demand must also be considered. In the case of capital mobility, Fleming (1971) argues that what matters for the effect is the nature of imbalances, how sensitive investment is to the level of economic activity and the period under consideration. High capital mobility implies the high elasticity of substitution of assets or debts of two countries. Mongelli (2005) adds that the mobility of capital is dependent on the speed and amount it can be generated in the investing economy and be absorbed in the other one where the investment occurs.

Kenen (1969) values *diversification* in production and output above evenlabor mobility, as well as the quantity of totally specialized regions in one country: even if disturbances exist for individual products or sectors, they can at least balance out if the products are not related and the exchange rate is not needed as an adjustment mechanism. One prerequisite for this stabilizing effect is sufficient labor and factor mobility, which is questionable when diversification is high. A counterargument is that a common central

[55] Even before that, Abba Lerner (1944) and Milton Friedman (1953) introduced the idea of factor, labor, and capital mobility to allow for smooth adjustment within a country after a negative shock in a single region, since currency devaluation in response to an internal shock is not obvious.

bank is better able to respond to similar types of shocks. *Symmetry of shocks* is more likely with a higher degree of goods market integration, less diversification, and a higher degree of *synchronization of business cycles* (Kenen ,1969; see also Fleming (1971) and Mongelli (2005)).

Willett and Tower (1970) and McKinnon (2004) question the empirical importance of Kenen's (1969) hypothesis that highly *diversified* economies are better candidates for currency areas and argue that in more diversified economies, foreign goods are better substituted by domestic goods, compared to less diversified economies, and that the exchange rate would fluctuate less regardless. Additionally, more diversified economies have a relatively low marginal propensity to import and are thus relatively closed in terms of Mc Kinnon's (1963) definition of *openness* as the ratio of tradable to non-tradable goods. However, the openness criterion actually states that an open economy with a large number of tradable goods is strongly influenced by international prices. This makes a flexible exchange rate less important (McKinnon, 1963; Tavlas, 1993; Eichengreen and Bayoumi, 1996).

Similar (low) inflation rates between countries lead to stable terms of trade and exchange rate adjustments less important (Tavlas, 1993). Persistent inflation differentials may be due to differences in inflation and unemployment tolerances and preferences and thus to divergent policies and differences in structural development (Mongelli, 2005). High and fluctuating inflation rates reduce the purchasing power of money and impair the function of money as a store of value. Therefore, a country with credible and stable government policies will have less inflation and enjoy a better reputation (Barro and Gordon, 1983).[56] To achieve *credibility*, Beine et al. (1999) suggest that countries can try to hold the exchange rate constant before entering a currency, even if they face divergences between the business cycles. Another possibility is to peg the currency to a credible one or to join a currency area. Thus, credibility may lead to similarity being an outcome rather than a precondition for a peg or common currency area, so it is with respect to inflation rates: similarity may also arise as a result of participation in a currency

[56] For an analysis how countries can become more credible, see Tavlas (1993).

area (Gandolfo, 1995).

Close links between potential members of a monetary union also help rebalancing after shocks and reduce the need for adjustment via the exchange rate. These include a high degree of *financial integration*, *policy integration,* and the *intensity of trade* (see, for example, Ingram, 1962; Fleming, 1971; Imbs, 2004; Azcona, 2022). Frankel and Rose (1997) agree that the intensity of trade is an important factor concerning optimal currency areas but they propose that this effect is endogenous and arises through economic integration and need not be a precondition. They further explain that through closer linkages within a currency union, *business cycles* can become more similar and are thus endogenous[57] as well, especially if demand shocks or shocks that affect all participating members overweight individual asymmetric shocks that could occur if countries become more specialized. The latter would result in more idiosyncratic business cycles.[58]

Some studies analyze formally or empirically the individual criteria as determinants of the incidence of shocks (e.g., diversification) (see Kenen, 1969; Bayoumi, 1994; Melitz, 1995; Mongelli, 2005; Duran and Ferreira-Lopes, 2017; Trenkler and Weber, 2020; Artis et al., 2008) or as criteria that facilitate adjustment (e.g., factor mobility) (see, among others, Meade, 1957; Ingram, 1973; Krugman, 2012). Others focus on the analysis of shocks and business cycles. The idea behind this is that symmetric disturbances can be treated with a common monetary policy. One strand of this literature analyzes to what extent supply and demand shocks in countries are correlated, following Bayoumi and Eichengreen (1993), who disentangle demand and supply shocks and estimate their correlations. A high degree of correlation is associated with symmetric shocks. They argue that while demand shocks have temporary effects, supply shocks have permanent effects on output. Therefore, they follow Blanchard and Quah (1989) and Eichengreen (1993) to decompose permanent from temporary shocks using a vector

[57] There are more proposals for endogenous effects of monetary unification. For example, De Grauwe and Mongelli (2004) explain the endogeneity of monetary integration, financial integration, symmetry of shocks, and product and labor market flexibility.
[58] For example, Eichengreen (1992), and Kenen (1969) explain this effect.

autoregressive (VAR) model.[59,60]

Another strand of the literature focuses on the dynamics of shocks using a test for common features. Beine, Candelon, and Hecq (2000) argue that the distinction between short- and long-run dynamics is crucial for OCA analysis, as the exchange rate is a suitable adjustment mechanism in the short run but not on the long-run. Here, structural policies are needed. In their multivariate VAR model with cointegration and common cyclical features, they are able to distinguish between short-run dynamics that are driven by common cycles and long-run dynamics that are driven by common trends. They follow Engle and Kozicki (1993) and Vahid and Engle (1993, 1997) and apply serial correlation common features tests and test for codependence to analyze whether short-run fluctuations across countries are (perfectly) synchronized. Engle and Kozicki (1993) investigate whether features found in a single dataset can also be recognized as common in multivariate datasets. A feature is said to be common if it occurs in every single series but not in every linear combination. The serial correlation common features test is used for this purpose.[61] The test for codependence by Vahid and Engle (1993) is less strict and relaxes the test for common features, as the linear combination need not be free of correlation with the past, but it is of a lower moving average order. This strand of literature argues that even if countries are affected by shocks that are highly correlated or common, their cycles may have different characteristics and comovement and persistence should also be considered. Correlation-based approaches, such as that of Bayoumi and Eichengreen (1993), are commonly used, but correlations analyzed are contemporaneous and static.

[59] See, among others, Fidrmuc and Korhonen (2003), Pentecôte and Huchet-Bourdon (2012), Campos and Macchiarelli (2016), Bayoumi and Eichengreen (2020), Deskar-Škrbić et al. (2021), Kunovac et al. (2022).
[60] Other studies that try to measure the magnitude of asymmetric shocks exist. Poloz (1990), Eichengreen (1992) and De Grauwe and Vanhaverbeke (1991) calculate the variability of real exchange rates, since changes in relative prices reflect shifts in demand or supply that affect one country relative to another. Cohen and Wyplosz (1989) and Weber (1990) use output data, transform them into sums and differences, remove their trend component, and interpret the standard deviation of the detrended series relative to the standard deviation of the original series as a measure of the contribution of temporary disturbances to overall variability. In doing so, they interpret movements in the sum as symmetric disturbances and movements in the differences as asymmetric disturbances.
[61] Breitung and Candelon (2000, 2001) develop this approach further on the frequency domain and examine comovement at particular business cycle frequencies.

2.3 Conceptual Framework

To motivate the use of the serial correlation common feature test that is frequently applied in the OCA literature, my co-authors Sven Steinkamp and Frank Westermann and I set up a simple model in the classical Barro-Gordon (1983) framework. This model builds on Berger et al. (2001), who have analyzed the optimal exchange rate regime choice in the presence of contemporaneous country-specific shocks. The decision on the exchange rate regime in this model is based on the difference in expected losses in both regimes. Our contribution is to highlight the effects of autocorrelated shocks and to trace their effects on the inflation bias, output, and welfare.

First, we analyze the case of *flexible exchange rates*. We start with a stochastic version of the Lucas-supply schedule:

$$y = \alpha(\pi - \pi^e) + \varepsilon_t,$$

where y is output, π the inflation rate, and π^e is expected inflation. ε_t is an error term, which we assume to follow an AR(1) process, $\varepsilon_t = \gamma\varepsilon_{t-1} + v_t$. v_t is a white noise shock, and γ measures the degree of persistence of the shock. We assume $0 < \gamma < 1$, i.e. ε_t is positively autocorrelated but the stochastic process is stationary. The central bank minimizes the following quadratic loss function,

$$L_{flex} = E[\lambda(\alpha(\pi - \pi^e) + \gamma\varepsilon_{t-1} + v_t - y^*)^2 + \pi^2] \quad (5)$$

subject to the inflation rate.[62] For simplicity, we assume that the central bank can control the inflation rate directly. The time-structure of the model is as follows: α, λ, as well as foreign inflation and the output target, π^*, y^*, are predetermined. At the beginning of the period, workers form inflation expectations. The central bank then chooses the optimal inflation rate after observing the shock v_t, which has zero mean and a variance of σ_v^2. Thereafter, y and L follow from the Philipscurve based on π and π^e. Equilibrium values for π and y are then given by the following:

[62] A micro-founded justification for the reduced-form relations in the Barro-Gordon model is derived in Reis (2003).

$$\pi = \alpha\lambda(y^* - \varepsilon_{t-1}\gamma) - \frac{\alpha\lambda}{(1+\alpha^2\lambda)} v_t \quad \text{and} \quad y = \gamma\varepsilon + \frac{1}{1+\alpha^2\lambda} v_t$$

These expressions simplify to the familiar expressions in the literature when setting the persistence parameter γ equal to zero.

Lemma 1. *The persistence of shocks affects the inflation bias.*

Proof.

$$E_t[\pi]^{\gamma\neq 0} = \alpha\lambda(y^* - \varepsilon_{t-1}\gamma). \qquad E_t[\pi]^{\gamma\neq 0} - E_t[\pi]^{\gamma=0} = -\varepsilon_{t-1}\alpha\lambda\gamma.$$

Depending on the sign of the shock in the previous period, this effect can either strengthen or reduce the inflation bias. This preliminary result is known from Bleaney (2001), who derives the implications for inflation persistence, which is shown to depend on the degree of shocks' autocorrelation and the exchange rate regime.

More importantly in the context of our overall question on the impact of persistence on the optimal exchange rate regime choice is the following finding that can be derived by plugging the values for π and y into the loss function.

Lemma 2. *The shock persistence does not affect expected losses in a flexible exchange rate case.*

Proof.

$$L_{flex}^{\gamma>0} - L_{flex}^{\gamma=0} = -\lambda\gamma\varepsilon(\lambda\alpha^2 + 1)(2y - \gamma\varepsilon) \; and \; E[L_{flex}^{\gamma\neq 0}] - E[L_{flex}^{\gamma=0}] = 0.$$

It is important to keep in mind that while the government chooses the optimal inflation rate after observing the shock, the shock is still a stochastic variable when the exchange rate regime is decided upon. Therefore, its mean-zero characteristic must be considered when computing the expected aggregate welfare loss. Under flexible exchange rates, when a central bank can fully respond to positive and negative shocks, the autocorrelation does not constitute an additional welfare loss to the economy.[63]

[63] In other words, in our model, the additional welfare effect of the regime choice in the presence of shock persistence is caused by differences in the ability to conduct macroeconomic stabilization alone and is not

Next, we consider the case of *fixed exchange rates* or, equivalently, a small country that joined a monetary union (permanently fixed exchange rates). We have the same autocorrelated output-function, $y = \alpha(\pi - \pi^e) + \varepsilon_t$ with $\varepsilon_t = \gamma\varepsilon_{t-1} + v_t$, but inflation, in this case, is determined by the purchasing power parity, which is given by

$$\pi = \pi^* + \theta_t,$$

where θ_t is the shock from the foreign country, which we also assume to be autocorrelated:

$$\theta_t = \delta\theta_{t-1} + u_t,$$

where u_t is a white noise shock and δ captures the degree of persistence of shocks in the foreign country. The output of the home country is therefore $y = \alpha u_t + \gamma\varepsilon_{t-1} + v_t$. We can plug both expressions into the loss function:

$$L_{fix} = E[\lambda(\alpha u_t + \gamma\varepsilon_{t-1} + v_t - y^*)^2 + (\pi^* + \delta\theta_{t-1} + u_t)^2] \tag{6}$$

As the central bank has fixed its exchange rate and is importing the inflation rate from abroad, the inflation rate is no longer a choice parameter.

To focus on the asymmetric persistence and its implications for welfare and exchange rate regime choice, we now set $u = v$. In other words, the stochastic elements of the time-series process are identical, and any differences are only driven by the persistence parameters δ and γ. In the terminology of the OCA theory, this captures the case of symmetric shocks with asymmetric effects.[64]

Proposition 3. *When joining a monetary union, an additional welfare gain/loss occurs from asymmetric persistence.*

Proof. $E\left[L_{fix}^{\delta\neq\gamma}\right] - \mathrm{E}\left[L_{fix}^{\delta=\gamma}\right] = \mathrm{var}(\theta_t)(\delta^2 - \gamma^2)$, *with* $var(\theta_t) = \frac{\sigma_v^2}{(1-\delta^2)}$.

affected by the credibility of monetary policy. For recent research on the latter, see, for example, Clerc et al. (2011) and Chari et al. (2020).

[64] Kohler (2002) shows how the presence of externalities and incentives to free ride may create additional welfare costs for joining a monetary union, even when shocks are symmetric.

The expression is zero if, and only if, $\delta = \gamma$.

Note that the expression for the additional welfare effect can become negative if shocks are more persistent in the joining country than in the monetary union ($\gamma > \delta$). In other words, an argument always exists to anchor unilaterally against a stable country. It follows that common persistence in two countries forming a monetary union is a new criterion for optimal currency areas, which has not been postulated formally in the literature to date.

Corollary 4. *The only symmetric equilibrium where two countries find it optimal to form a monetary union is the when* $\delta = \gamma$.

2.4 From Model to Data

The empirical implication from the conceptual framework discussed above is that the persistence of shocks in two countries forming a monetary union should be identical. A typical way to measure the persistence is examining estimates of the half-lifes.

This simplified approach, however, has two shortcomings. First, the standard errors of half-life estimates are known to be large. Thus, this is hardly a reliable source of information. Secondly, this approach abstracts from the possibility of higher-order autoregressive processes, which are common in quarterly macroeconomic data. Most time series on GDP typically display both a partial autocorrelation function that is significant for about four to six quarters and a strong seasonal pattern.

When extending Proposition 3 to higher-order AR(p) processes of the same order for θ and ε, we get the following expression for the additional welfare loss under asymmetric persistence:

$$var(\theta_t)\sum_{p=1}^{P}\left(\delta_p^2-\gamma_p^2\right)+2var(\theta_t)\sum_{p=1}^{P-1}\sum_{q=p+1}^{P}\varphi_{q-p}\left(\delta_p\delta_q-\gamma_p\gamma_q\right) \tag{7}$$

Thus, not only the persistence parameters of the AR(1)-term but all coefficients in the AR(p) process must be identical for this expression to be zero, i.e., $|\delta_i| = |\gamma_i|,\ \forall i.$ Intuitively, equation (7) can be interpreted as the expected squared deviation of the two processes.[65]

The empirical approach of a SCCF test, which was developed by Engle and Kozicki (1993) and that has been applied in the context of the OCA and business cycle synchronization literature[66] thus indeed constitutes a model-consistent empirical

[65] There are two additional zero points. A naïve solution exists if the common shock has a zero variance. Furthermore, the welfare loss becomes zero if the first summand of Eq. 3 is equal to the negative second summand. This, however, requires the AR-coefficients to be very distinct linear combinations of each other. For example, it requires $\gamma_2 = \delta_1\gamma_1 - sqrt\left(\delta_1{}^2\left(-\delta_2{}^2+\gamma_1{}^2+1\right)+(\delta_2-1)^2\left(\delta_2{}^2-\gamma_1{}^2\right)\right)/(\delta_2-1)$ in the AR(2) case. Intuitively, this situation arises if the expected deviations in different periods exactly offset each other, i.e. if the imported spillover at time *t* equals the "re-export" of the same shock in later periods.

[66] See, for example, Beine et al. (2000), Candelon et al. (2005), Hecq et al. (2006), Sato and Zhang (2006), Cubadda et al. (2013), and Trenkler and Weber (2020).

approach to assess the existence of an optimal currency area. It tests for a common higher-order AR(p) process in different time series by identifying the existence of a linear combination of two variables that is free of autocorrelation. An alternative interpretation of the SCCF is that the impulse response patterns of two variables, when faced with a common exogenous shock, must be identical.

Since the first proposal of the SCCF by Engle and Kozicki (1993) and Vahid and Engle (1993, 1997), several advancements to the testing procedure that are relevant to our dataset have been proposed. First, as shown by Cubadda (1999), the co-existence of seasonality and autocorrelation requires an integrated approach to modeling the data. The usage of de-seasonalized data may lead to an incorrect finding of common cycles. As all countries in our dataset indeed have a seasonal component, this point is particularly relevant for our analysis.

In the empirical section, we first consider the long term trend dynamics before finally conducting the common serial correlation test. We perform both the strong form of the SCCF test, as well as the less restrictive test for codependence, which was first discussed in Vahid and Engle (1997).[67]

[67] However, the test for scalar components models of order (0, *q*) by Tiao and Tsay (1989) can also be interpreted as the first consistent, but non-optimal, test for codependent cycles.

2.5 European Monetary Union

2.5.1 Institutional Analysis of the Euro Area

Under the Treaty on the Functioning of the European Union, all EU countries are obliged to adopt the euro. However, this requires the countries to meet certain convergence criteria. These criteria, as well as the status of the candidate countries that have not yet adopted the euro, are explained in this section, following a brief outline of the history of the EU.[68]

After the Second World War, conflicts in Europe were to be ended and peace promoted. In this spirit, the first precursor of the European Union, the European Coal and Steel Community (ECSC), was founded in 1952.[69] The starting point for this was a speech of the French Foreign Minister, Robert Schuman, on May 9, 1950 (Schuman, 1950). He proposed that the armaments-related industries of the Western European countries, in particular coal and steel, be placed under the control of a common authority. The next step followed in 1957, when, with the "Roman Treaties" the European Economic Community (EEC) and the European Atomic Energy Community (EAEC) were founded. A common parliamentary assembly and one assembly of the European Communities (EC), ECSC, EEC and EAEC, were also established. In 1967, the Merger Treaties and the merging of Commissions and Councils of Ministers created the European Community with a single administration, the Commission, and the Council, as a common executive. In 1973, Ireland, Denmark, and the United Kingdom join the European Communities, followed by Greece in 1981 and Spain in 1986. However, this period of closer cooperation is overshadowed by the Cold War.

On February 7, 1992, the Treaty on European Union was signed in Maastricht, establishing the Economic and Monetary Union[70]. It lays down rules on not only foreign and security policy, justice, and home affairs but also the future single currency and entered into force on November 1, 1993. At the beginning of 1993, the single market

[68] Information on the history of the EU are retrieved from European Parliament (2018).
[69] The founding members were France, Germany, Belgium, Netherlands, Luxembourg, and Italy.
[70] The formation of the EMU, a central step in the integration of the EU countries, involved the coordination of economic and fiscal policies, a common monetary policy, and the euro as common currency.

(called the "internal market") was introduced, bringing with it four freedoms: the free movement of people and of goods, services, and capital.[71] In 1995, three more countries joined the EU: Finland, Sweden, and Austria. On January 1, 1999, the euro was introduced as a legal book currency in 11 countries,[72] followed by the introduction of banknotes and coins in 2002 in these countries and Greece, which joined the EU in 2001. Under the Treaty of the Functioning of the European Union, all European Union countries are obliged to adopt the euro, which implies that they must fulfill the convergence criteria. Only one country, Denmark, negotiated a derogation and was granted an opt-out option.[73] Thus, Denmark need not have to adopt the euro, even if all convergence criteria are fulfilled.[74]

On May 1, 2004, 10 more countries,[75] the majority of which are central and Eastern European countries, joined the EU. Bulgaria and Romania followed on January 1, 2007, so that the EU at that time comprised 27 states, of which only 12 use the common currency. Some of these countries have already adopted the euro by now. Slovenia joined the euro area on January 1, 2007. Cyprus and Malta adopted the euro on January 1, 2008, and Slovakia followed at the beginning of 2009. The Baltic countries followed some distance behind: Estonia introduced the euro in 2011, Latvia in 2014, and Lithuania in 2015.

After the EU continued to grow, efforts were made in the United Kingdom to leave it again. In a referendum in June 2016, 52% of British voters voted in favor of the UK leaving the EU. Ultimately, the UK left the EU on January 31, 2020.

The last accession country was Croatia, which joined the EU in 2013 and adopted the euro on January 1, 2023.[76] In total, the euro is now the currency of 20 of the 27 EU

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[71] One year later, on January 1, 1994, the European Economic Area was created. This expanded the single market to include the countries of EFTA and the four freedoms to apply in 30 countries: the 27 EU countries plus Iceland, Liechtenstein, and Norway. Switzerland is not a member of the EEA, but the four freedoms apply here as well.

[72] These countries were Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain.

[73] At present, this opt-out option does not exist for any other country.

[74] Nevertheless, the Danish krone has been in ERM 2 since January 1, 1999.

[75] The accession countries are Estonia, Latvia, Lithuania, Poland, Slovakia, Slovenia, Czech Republic, Hungary, Cyprus, and Malta.

[76] Croatia has been part of the ERMII since July 10, 2020.

countries, and six countries (Denmark has a derogation) are committed under the Treaty on the Functioning of the European Union to adopt the euro, which implies that they must strive to fulfill the convergence criteria.

The convergence criteria were set in the Treaty on the European Union (Maastricht Treaty)[77] as the common currency implies that a flexible exchange rate no longer exists between countries and that there is a common central bank that decides monetary policy for the entire euro area. To ensure that a country's economy is ready for the introduction of the common currency and that no problems arise for the existing euro area or the country in question, criteria have been established to ensure economic convergence, as follows:[78]

- Price stability: The acceding Member States should achieve a high degree of price stability. A price performance is seen as sustainable if the average harmonized consumer price inflation (HICP), observed over a period of one year before the examination, does not exceed 1.5 percentage points above the rate of the three best-performing Member States in terms of price stability (see Treaty on European Union, Art. 140(1), first indent). The relative consideration of price stability compared with other countries considers general shocks that could cause inflation rates to temporarily deviate from central bank targets.

- Sound and sustainable public finances: Measured by government deficit and debt, the country should not be excessive deficit procedure at the time of examination[79] (see Treaty on European Union, Art. 140(1), second indent). According to the Stability and Growth Pact, laid down in the treaty, fiscal discipline is fulfilled if (i) the ratio of the planned or actual government deficit to GDP is smaller or equal to 3%[80] and (ii) the ratio of government debt to GDP does

[77] The Treaty on European Union was signed on February 7, 1992 and entered into force on November 1, 1993.

[78] See European Commission (2022a).

[79] The Council, which coordinated economic policymaking in the EU, decides on the basis of Article 126(6) of the Treaty on European Union whether an excessive deficit exists. In this Article, the steps of the Excessive Deficit Procedure (EDP) are also outlined. The Treaty on Stability, Coordination, and Governance in the Economic and Monetary Union (Art.3) adds the rule that the structural deficit not exceed 0.5% of GDP (European Commission, 2022a).

[80] Exceptions are a continuous declining ratio that comes close to the reference value or if the excess is

not exceed 60%[81] (European Commission, 2022a).

- Exchange rate stability: The country under consideration must participate in the ERM II[82] for at least two years without severe tensions, in particular without devaluation of its bilateral central rate against the euro. A stable exchange rate is associated with confidence in prices for import and export (see Treaty on European Union, Art. 140(1), third indent). The currency of the candidate country is allowed to fluctuate up to 15% around an agreed central rate between the euro and the country's currency.[83]

- Durability of convergence: The average nominal long-term interest rate,[84] observed over a period of one year before the examination, should not exceed the rate of the three best-performing EA countries by more than 2 percentage points in terms of price stability (see Treaty on European Union, Art. 140(1), fourth indent).

In addition to these convergence criteria, the national laws and rules of the respective country must be amended in such a way that they fit the provisions of this treaty. This includes, in particular, the independence of the national central bank, so that the ECB's monetary policy can then also be independent. The treaty also states that other factors affecting convergence and economic integration should be considered, including the integration of markets and the development of the balance of payments.

The fulfillment of the criteria by the accession candidates is reviewed by the Commission and the European Central Bank at least every two years or at the request of a member state with a derogation, and the result is published in the Convergence Report. According to the most recent Convergence Report from 2022, overall, only Croatia fulfills the criteria for the adoption of the euro. All other acceding countries to the euro area do not fulfill several criteria, have individual weaknesses, and need action to adopt

only temporary and exceptional and remains close to the reference value.

81 An exception is a diminishing and approaching ratio.

82 The ERM II replaced the ERM as of January 1999.

83 If necessary, interventions coordinated by the ECB and the individual central bank can support the compliance of the fluctuation bands.

84 The nominal interest rates shall be measured by long-term government bonds or comparable securities.

the euro.

Summarized information on the individual convergence criteria, as reported in the most recent Convergence Report (2022), is presented in Table 2.1. For this report, the average inflation rate to evaluate *price stability* covered the period from May 2021 until April 2022, calculated in relation to the previous 12-month average. The reference value, which consists of the three best-performing Member States in terms of price stability, has been built by taking the unweighted arithmetic average of the rates of inflation of France (3.2%), Finland (3.3%), and Greece (3.6%)[85] and adding 1.5 percentage points. Thus, the reference value for inflation in the most recent Convergence Report is 4.9%. The individual countries' inflation, except for Sweden and Croatia, exceeds the reference value.

To evaluate the fulfillment of *sound and sustainable public finance*, the Council determines whether the country has an excessive deficit on the basis of Article 126(6) of the Treaty. The first criterion, government deficit to GDP ≤ 3%, is met by Sweden, Croatia, and Poland. The remaining countries exceed it. However, the excess is considered exceptional due to COVID-19 for Bulgaria, the Czech Republic, and Hungary, as these countries met the deficit target in several reviews before the COVID-19 pandemic. Only Romania is in excessive deficit. The second criterion, government debt to GDP ≤ 60%, is met by all countries except Croatia[86] and Hungary.

To meet the exchange rate criterion, the country should have participated in ERM II for at least two years prior to the review without experiencing severe tensions and, in particular, should not devalue its bilateral central rate against the euro. If the country in question has been part of ERM II for less than two years at the time of the review, the Convergence Report describes exchange rate developments over a two-year reference period, which is May 26, 2020 to May 25, 2022 for the 2022 Convergence Report. Bulgaria has been participating in ERM II with its currency, the Bulgarian lev, since July 10, 2020, maintaining its currency board arrangement,[87] and has not deviated from its

[85] The euro area average is 4.4%.
[86] For Croatia, this is evaluated as an exception by the European Commission.
[87] Bulgaria implemented its currency board in 1997. The anchor currency was first the German mark and later the euro.

central rate of 1.95583 lev per euro (with a standard fluctuation band of +- 15%) during the reference period. The Croatian kuna has been part of the ERM II since July 2020. The central rate is at 7.53450 kuna per euro, with a standard fluctuation band of +-15%. During the reference period, the low volatility was well below the fluctuation bands. Romania has a managed floating regime with the euro, and the flexible exchange rate shows low volatility. Hungary and Poland each have a de jure flexible exchange rate against the euro, which both show high volatility in the reference period. The Czech koruna has a de jure flexible exchange rate relative to the euro and is not part of ERM II. The exchange rate shows a relatively high degree of volatility. The exchange rate of the Swedish krona to the euro is de jure flexible and shows a high degree of volatility in the reference period.

The long-term interest rates have been calculated as an arithmetic average from May 2021 to April 2022 for the recent convergence report. The reference value for this criterion is the unweighted arithmetic average of the long-term interest rates of the three best-performing Member States – France (0.3%), Finland (0.2%), and Greece (1.4%) – plus two percentage points. This results in a reference value of 2.6%. All countries except Poland, Hungary, and Romania fulfilled the criterion and had long-term interest rates below 2.6%. Three countries, namely Sweden, Bulgaria, and Croatia, showed long-term interest rates close to the rate of the euro area, which was 0.4%. The Czech Republic was just below the reference value.

The treaty further requires the report of other relevant factors, including information on the integration of markets, the development of balances of payments on current account, and information on prices as unit labor costs and other price indices. This is combined with a surveillance framework, the macroeconomic imbalance procedure (MIP), which includes an alert mechanism for the early detection of imbalances. Among other points,[88] the European Commission concluded for all acceding countries except Croatia that the country-specific law does not meet all requirements for central bank independence, the monetary financing prohibition, and legal integration into the euro system. In 2022, three countries were selected for an in-depth review in the Alert

[88] See the Convergence Report 2022 (European Commission, 2022a) for more details.

Mechanism Report 2022 by the European Commission. Croatia has been selected due to continuing imbalances relating to high levels of external, private, and government debt in the context of low potential growth. In Romania, the most severe issues are related to its external position and cost competitiveness. According to the European Commission, concerns exist about low productivity levels and weak quality of the country's institutions and governance. The third country, Sweden, shows macroeconomic imbalances derived from the housing market, as residential property prices have risen sharply since spring 2020, which seems to deviate significantly from historical fundamentals, such as mortgage rates or household disposable income.

Table 2.1 Summary: Fulfilment of Convergence Criteria

	Price stability	Government budgetary developments and projections			Exchange rate		Convergence durability
	HICP inflation	Country in excessive deficit	General gov. surplus (+) /deficit (-)	General gov. debt	Currency in ERM II	Exchange rate vis-à-vis the euro	Long-term interest rate
Bulgaria	5.9	No	-3.7	25.3	Yes	0.0	0.5
Czechia	6.2	No	-4.3	42.8	No	3.9	2.5
Croatia	4.7	No	-2.3	75.3	Yes	-0.2	0.8
Hungary	6.8	No	-6.0	76.4	No	-3.1	4.1
Poland	7.0	No	-4.0	50.8	No	-1.5	3.0
Romania	6.4	Yes	-7.5	50.9	No	-0.5	4.7
Sweden	3.7	No	-0.5	33.8	No	-3.0	0.4
Reference value	4.9		-3.0	60.0			2.6

Note: Summary of fulfilment of convergence criteria as reported in the Convergence Report 2022 by the European Commission.

Overall, only one of the acceding countries participates in ERM II and has concrete plans to adopt the euro. Bulgaria joined ERM II in July 2020 and plans to adopt the euro in 2024. Romania is preparing to join but is not yet part of ERM II. The remaining countries are pushing less to adopt the euro.

The European Commission regularly publishes the results of telephone surveys of the population of the candidate countries on various topics related to the introduction of the euro.[89] According to the April 2022 Flash Barometer, with a total of 7,074 participants, 60% of the population on average in the countries are in favor of the introduction of the euro. Of these, only 23% are "very much in favour" and the majority (37%) are "somewhat in favour". Of the population of the candidate countries, 28% are against the introduction of the euro, of which 17% say they are "very much against" it. The greatest opposition to the euro is among the population in the Czech Republic. Overall, 55% of the Czech population is against the introduction of the euro, of which the majority (29%) are "very much against its introduction". Other countries where more than 50% oppose the introduction of the euro are Bulgaria (53%) and Sweden (51%). The highest number of people in favor of the introduction of the euro is in Romania (77%), and the highest number of people "very much in favor of its introduction" is in Poland.[90]

Preferences on the date of the introduction of the euro were also surveyed. The picture is similar to that for the question of whether the euro should be introduced. Thus, 28% stated that the euro should be introduced "as soon as possible", 34% "after a certain time" and 36% "as late as possible/ never". The introduction "as soon as possible" or "after a certain time" reaches a majority in Romania, Hungary, Poland, Croatia and Bulgaria. In the Czech Republic and Sweden, however, 52% and 55%, respectively, agree. Most of the participants who would like to introduce the euro as soon as possible come from Romania (43%) and Hungary (36%).

[89] More details and the original questionnaire with all questions can be found in the Flash Barometer 508, April 2022 (European Commission, 2022b).

[90] The question was "Generally speaking, are you personally more in favor or against the idea of introducing the euro in (THIS COUNTRY)?". There were five possible answers: "Very much in favor of its introduction", "rather in favor of its introduction", "rather against its introduction", "very much against its introduction", and "don't know".

Even if the introduction of the euro is supported, more than 50% of the population agree with the statement that the country is ready for the introduction of the euro in any country. On average across the countries, 28% agree with the statement, and 67% think that the respective country is not ready for the introduction of the euro. The highest level of agreement was in Croatia (37%), and the highest level of disagreement with the statement was in Hungary (72%).[91]

Although not all candidate countries have popular support for the introduction of the euro, these countries are obliged to adopt it. However, they do not yet meet the formal convergence criteria. Nevertheless, the suitability of the countries to join the euro area is analyzed in this analysis from an economic perspective using common feature tests.

2.5.2 Literature Review

In the context of OCA literature, to detect common business cycles or responses to shocks, several studies applied common features testing procedures following Engle and Kozicki (1993) and Vahid and Engle (1993) and codependence tests following Vahid and Engle (1997) to nowadays members of the European Monetary Union, as well as still acceding countries to the euro area. Engle and Kozicki themselves considered G7 countries. Beine, Candelon and Hecq (2000) use monthly, not seasonally adjusted industrial production indexes from 1975M1 until 1977M4 and find no evidence for a unique common cycle and thus no evidence for a perfect OCA. Applying the less strict test for codependence, which allows for an initial adjustment period, they find evidence for a common cycle for Germany, Belgium, and the Netherlands after an adjustment period of five months. They argue that a common reaction with a delay of a year or five months may not be enough to form an OCA.

Breitung and Candelon (2000) focus on Austria, Germany, and the United Kingdom. The authors use seasonally unadjusted industrial production indices for the same period as Beine et al. (2000), 1975M1 to 1977M4 and use SCCF tests based on the

[91] In most cases, the results of the public opinion poll match the impression reported in the public media about the objectives of the respective government, but not in every country. According to media reports, Hungary and Poland (in contrast to the results of the survey) are also not striving to introduce the euro, and Sweden held a referendum in 2003. Bulgaria is in ERM II and aims to introduce the euro.

2SLS proposed by Engle and Kozicki (1993) and also on the canonical correlations proposed by Vahid and Engle (1993). They do not find evidence for a common cycle for both Germany and Austria and Germany and the United Kingdom using either method. Analyzing the frequency domain, they find a common cycle for Germany and Austria. The sample of countries is extended by Breitung and Candelon (2001) to include France and the Netherlands. For these countries, they also find evidence for a cycle each with Germany.

A more recent study by Cubadda et al. (2013) considers a period after the formation of the monetary union, from 1999Q1 until 2011Q1. They analyse the growth rates of quarterly seasonally adjusted real GDP data for 24 European countries and find evidence for a common cycle between 10 countries: Germany, France, Italy, Luxembourg, the Netherlands, Austria, Poland, Portugal, Slovenia, and Sweden. Cubadda et al. (2013) detect a second, peripheral group that shares a common synchronous cycle, but is not synchronous with the first group. These countries are Bulgaria, Denmark, Estonia, Ireland, Latvia, Hungary, Slovakia, Finland, Spain, and Cyprus. The remaining countries, the Czech Republic, Lithuania, and the United Kingdom, exhibit idiosyncratic cycles.

Trenkler and Weber (2020), use first differences of quarterly seasonally adjusted real GDP data from 1995Q1 until 2016Q2 to examine whether peripheral countries share a common cycle with a European core group. They consider Germany, France, Italy, the Netherlands, Belgium, and Austria as the core group and could not find evidence for common cycles for any of the peripheral countries: Greece, Ireland, Portugal, and Spain.

Many other studies and approaches have explored common business cycles or responses to shocks. Many of them have comparable results. For example, Beine et al. (1999) and Di Giorgio (2016) apply Markov-Switching models. Beine et al. (1990) analyze predominantly members of the euro area, except for the United Kingdom, Norway, Switzerland, and Sweden, for which, however, they find rather idiosyncratic cycles. Di Giorgio (2016) instead examines Central and Eastern European (CEE) countries for a common cycle with the euro area. He analyzes the Czech Republic, Slovakia, Lithuania, Latvia, Estonia, Poland, Hungary, Slovenia, Bulgaria, and Romania in a sample from 1993 until 2014 and finds similarities between the business cycles of the CEE countries and the euro area and that the synchronization between the business cycles is relatively high, especially during recessions. Among the countries considered, Hungary and Poland are most integrated with the euro area.

Two more studies focus on acceding countries to the euro area. Deskar-Škrbić et al. (2021) analyze the coherence of shocks between Bulgaria, Croatia, Romania and the euro area. They distinguish between individual and external shocks and consider the latter to be relevant for the ECB's monetary policy. In a sample that spans 2003Q1 to 2018Q2, their analysis relies on a structural Bayesian VAR and reveals that external ECB-relevant shocks are relevant in the three countries under consideration and that the countries' GDP and inflation responses are often not statistically significantly different from the euro area responses. From this, they conclude that the countries are ready for a common monetary policy. Nanovski (2022) contradicts these results for Bulgaria and Romania. He argues that to analyze whether countries are ready to abandon their independent monetary policy to enter a currency union, it is better to examine the synchronization of monetary policy recommendations rather than of business cycles. He finds that the Czech Republic and Croatia fit best with the core euro countries, while the two countries most forcing to adopt the euro, Bulgaria and Romania, do not.

The next section includes an empirical analysis of the acceding countries to the euro area. The examination starts with some preliminary analysis, followed by the common features tests and the tests for codependence. Some robustness analyses are then performed, and I compare the results for the countries joining the euro area with a group of countries whose currency is the euro across the sample.

2.5.3 Empirical Analyses – Europe

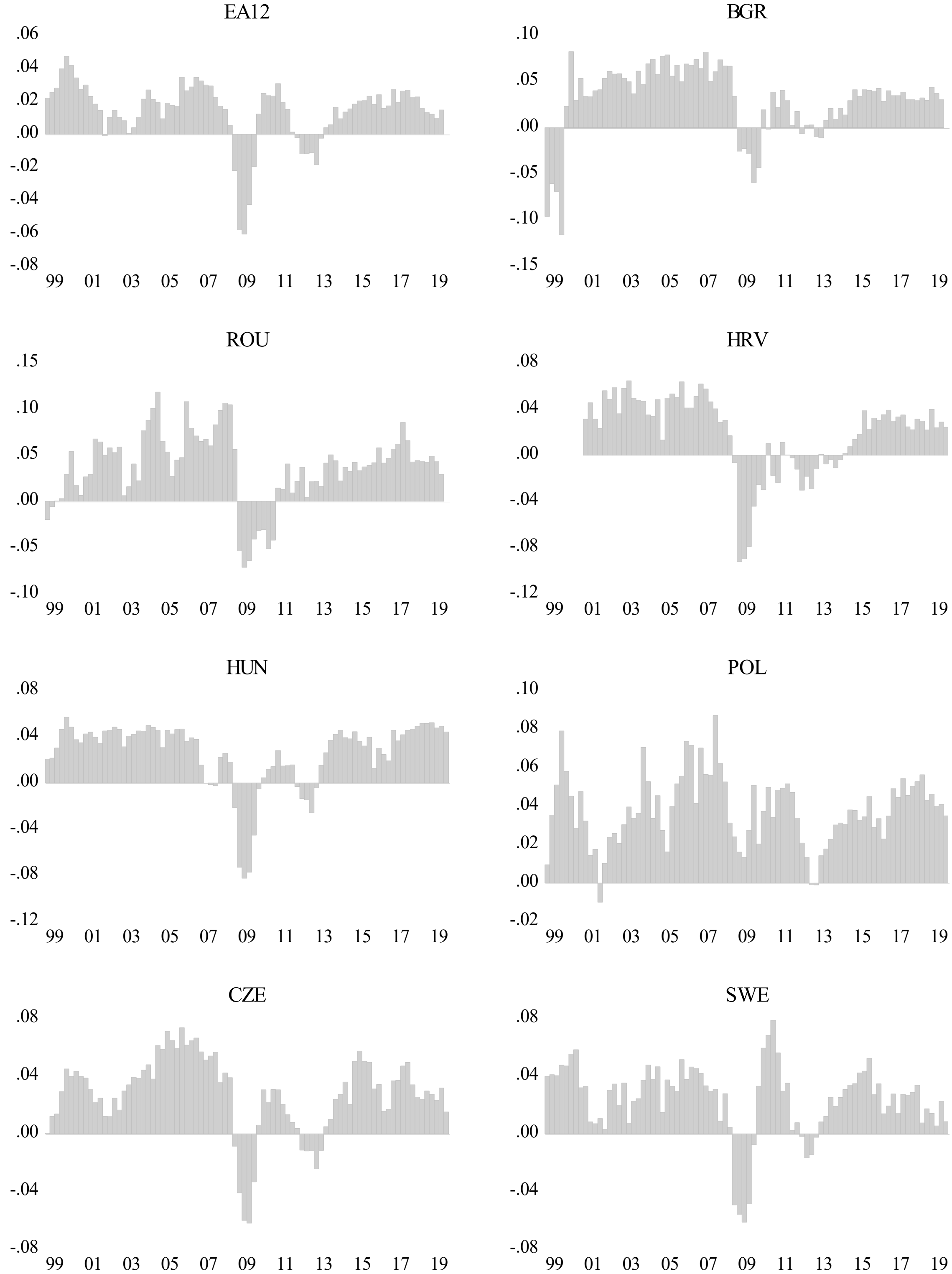
2.5.3.1 Data and Preliminary Analysis

Quarterly real GDP (not seasonally adjusted) data was extracted from Eurostat and ranges from 1999Q1 to 2019Q3. This means that Croatia is still in the group of accession candidates in this analysis, even though it adopted the euro in January 2023. The data is displayed in Figure 2.1 in seasonal differences. Eyeballing the data, we immediately see some commonalities across countries, such as the boom-period in the mid-2000s, the cyclical downturn after the global financial crisis in 2007/8, a rebound and a renewed recession after the beginning of the sovereign debt crisis in 2010, and another rebound thereafter. Since roughly 2012, most countries have displayed a relatively steady growth path.

We further estimate correlation coefficients and find a sizable degree of correlation between the seasonal growth rates of GDP. The coefficients are reported in Table 2.2 and are all statistically significant at the 1% level. The correlation between the GDP growth rates of individual countries and the EA12 aggregate is highest for Sweden and the Czech Republic, followed by Hungary and Croatia.

The empirical implication from the conceptual framework discussed in Section 2.3 is that the persistence of shocks in two countries forming a monetary union should be identical. A typical way to measure persistence is looking at estimates of the half-lifes, which are reported in Figure 2.2 for the set of acceding countries to the EMU. This preliminary inspection of the data suggests that the countries may indeed form an optimal currency area, as the persistence in the candidate countries is not statistically different from that of the monetary union.

Figure 2.1 Real GDP Growth Rates – Eurozone Accession Candidates



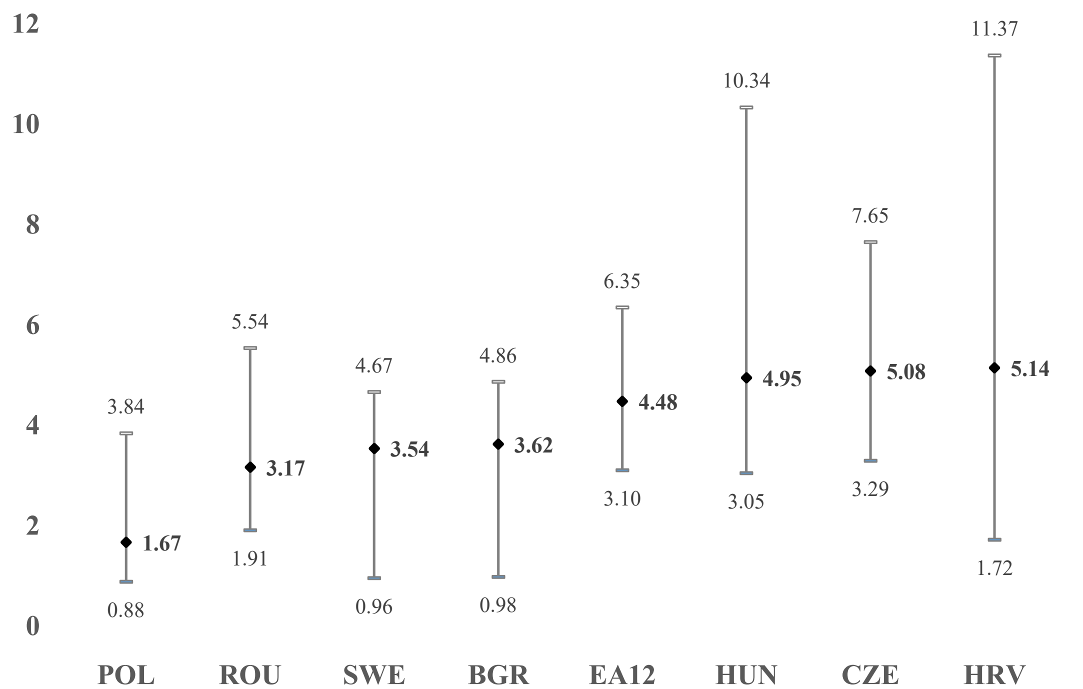
Note: Figure 2.1 depicts seasonal growth rates of real GDP (not seasonally adjusted) from 1991Q1 until 2019Q3 for Bulgaria (BGR), Czech Republic (CZE), Croatia (HRV), Hungary (HUN), Poland (POL), Romania (ROU), Sweden (SWE), and the founding euro area members (EA12), consisting of Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.

Table 2.2 Correlation Coefficients – Eurozone Accession Candidates

	BGR	ROU	HRV	HUN	POL	CZE	SWE
EA12	0.307***	0.442***	0.730***	0.760***	0.515***	0.810***	0.880***
	[2.90]	[4.43]	[9.13]	[10.54]	[5.41]	[12.44]	[16.65]

Note: Table 2.2 reports (Pearson) correlation coefficients between countries' real GDP growth rates (seasonal differences) between Bulgaria (BGR), Czech Republic (CZE), Croatia (HRV), Hungary (HUN), Poland (POL), Romania (ROU), Sweden (SWE) and the founding euro area members (EA12). t-statistics for the null of the coefficient being unequal to zero are given in parenthesis. *, **, *** indicate statistical significance at 10%, 5%, and 1% level, respectively.

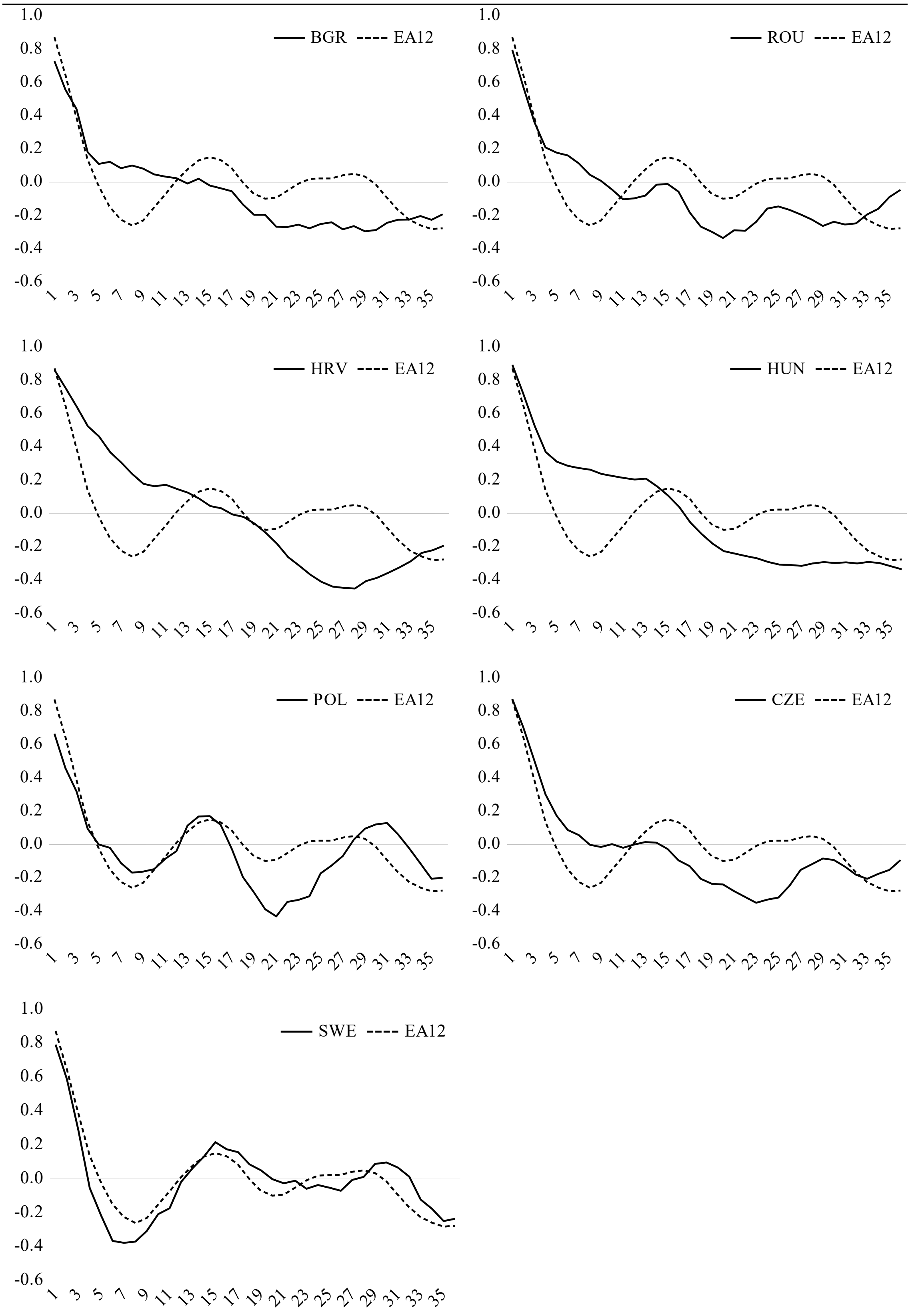
Figure 2.2 Half-life Estimates – Eurozone Accession Candidates



Note: Figure 2.2 depicts half-life estimates (+/– 2 standard errors) based on the impulse response of a vector autoregressive model with 4 lags (quarters) for Bulgaria (BGR), Czech Republic (CZE), Croatia (HRV), Hungary (HUN), Poland (POL), Romania (ROU), Sweden (SWE), and the founding euro area members (EA12).

A standard response to an exogenous shock is then displayed in Figure 2.3. For each country, we show the correlograms that display the autocorrelation of each time series. It can be interpreted as the cyclical response pattern of each country to an exogenous shock. In this representation of the data, we already see that the response patterns can be quite different across countries – despite the similarities of the half-lifes reported in Figure 2.2.

Figure 2.3 Autocorrelograms – Eurozone Accession Candidates



Note: Figure 2.3 shows estimated sample autocorrelation functions of real GDP growth rates (seasonal differences of logarithmized values) over 36 quarters for Bulgaria (BGR), Czech Republic (CZE), Croatia (HRV), Hungary (HUN), Poland (POL), Romania (ROU), Sweden (SWE), and the founding euro area members (EA12).

Each of the acceding countries in this figure is displayed together with the correlogram of the EA12 countries – the set of countries for which we have a consistent dataset of 83 observations as full Eurozone members.[92] The EA12 aggregate is characterized by a typical positive autocorrelation for about 4 - 5 quarters and a negative, but somewhat smaller, autocorrelation, for the subsequent 4 - 8 quarters. Thus, when accumulating these impulse response patterns in the GDP growth rates, one gets the typical up- and downswing patterns in the associated levels of GDP around its trend. Thereafter, further ups and downs occur, which are however statistically insignificant (we omit the standard errors in this graph for a better visual illustration for commonalities and differences in the point estimates).

The correlograms of the acceding countries, by contrast, are quite different. Except for Poland and Sweden, most countries display a much longer positive autocorrelation and a delayed cyclical rebound. Cumulatively, this would imply a much longer cycle. While this first pass gives a visual impression of the data, a formal test on the collinearity of impulse response patterns must be conducted to precisely pin down which country may fulfill the OCA criterion postulated in the previous section and which countries do now.

An integral part of the analysis of common cycles is the consideration of trends and seasonal elements in the data. We, therefore, start the formal regression analysis by conducting the respective tests needed for the subsequent analysis of common cycles. Table 2.3 reports the seasonal unit root tests (HEGY[93]), which shows that the time series of all countries are integrated at the zero frequency, a plausible finding, as all data are in logged levels. At the frequency $\pi/2$, all countries including the EA12 except Bulgaria and Croatia are stationary. The Czech Republic and Sweden are further stationary at frequency π. In terms of quarterly data, $\pi/2$ corresponds to one cycle per year, and π two cycles pear year, respectively.

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[92] The EA12 comprises Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and Greece. Our results are not affected by this choice and also hold, for example, for the EA19 countries. This is not surprising given a correlation between the two series of near unity.

[93] See Hylleberg et al. (1990).

Table 2.3 HEGY Unit Root Test – Eurozone Accession Candidates

	Frequency			
Country	0	PI	PI/2	All seasonal frequencies
EA12	-2.455	-2.179	14.803***	12.010***
Bulgaria	-1.919	-2.537*	3.240	4.910
Romania	-1.996	-1.747	7.308**	6.173**
Croatia	-2.305	-1.878	1.250	2.004
Hungary	-1.699	-2.653*	13.402***	12.517***
Poland	-2.403	-2.658*	11.690***	10.321***
Czechia	-2.202	-3.890***	10.252***	11.714***
Sweden	-3.286*	-2.939**	14.022***	11.974***

Note: Table 2.3 shows results from the HEGY seasonal unit root test (see Hylleberg et al., 1990) for log-levels of seasonally unadjusted GDP. Regressors include, intercept, trend, and seasonal dummies. Optimal lag order between 1 and 7 is derived automatically from the Akaike Information Criterion.

We consider these stationarity properties when testing for cointegration in the next step. Table 2.4 shows that all countries except for Romania, Hungary, and the Czech Republic indeed are cointegrated and thus share a common long-term trend with the EA12. Regarding the cointegration at frequency π, we find that Bulgaria and Poland also share a common stochastic seasonal trend with the EA12.

Table 2.4 Seasonal Cointegration Tests – Eurozone Accession Candidates

		0		π	
	Lags	r = 0	r ≤ 1	r = 0	r ≤ 1
Bulgaria	7	23.073***	0.217	16.342***	6.761
Romania	5	8.485	0.532	7.793*	3.103
Croatia	6	18.462***	2.112	8.017*	2.320
Hungary	6	11.625*	0.251	6.119	0.568
Poland	5	21.180***	0.022	15.258***	0.754
Czechia	5	7.885	0.000	–	–
Sweden	7	14.640**	3.334	–	–

Notes: Table 2.4 shows results from a bivariate (against EA12) seasonal cointegration test for log levels of seasonally unadjusted real GDP. Trace Statistics. *, **, *** indicates the rejection of the null based on linearly interpolated critical values of Lee and Siklos (1995). Optimal lag order between 1 and 7 is derived by Akaike Information Criterion of the bivariate VAR incl. deterministic trends and seasonal dummies.

While not directly relevant for the OCA literature, it is critical to consider these characteristics of the data when performing the common serial correlation test in the next section. We include – wherever necessary –the error correction term in the list of instruments when conducting the common features tests.

2.5.3.2 Codependence and Common Cycles

We now arrive at the main part of the analysis – the test for the existence of common cyclical patterns across countries, i.e. a common impulse pattern to an exogenous shock. The results are summarized in Table 2.5. In principle, two different approaches exist to conduct a common serial correlation common feature test: one is regression-based and one is based on canonical correlation analysis, similar to the Engel-Granger (1987) two-step and the Johansen multivariate approach to the cointegration test. In our exercise, we take the latter approach and estimate the parameters with 2SLS and with GMM.[94]

When starting with the strict form of identical impulse response patterns (serial correlation common features), we must consider the first column of test statistics and associated p-values, labeled “codependence of order zero”. This table illustrates that indeed, most of the countries do not share an exactly common impulse response pattern, not even Poland, which, after first eyeballing the data appeared to be quite similar to the EA12. The only country that does indeed appear to share a common impulse response pattern is Sweden.

A somewhat weaker definition of a common cycle could be used where the initial response (at lag 1) is allowed to be different but all subsequent lags are required to be identical. This is considered to be a codependent cycle of order one and may also be relevant for the OCA case, although it does not follow directly from our model. When applying this less strict criterion, Table 4 shows that the Czech Republic and Croatia also display some similarity in the sense of a common, but not perfectly synchronized common cycle. Finally, when considering higher orders, up to three, we find a common feature for all countries for at least one of the two testing procedures.

[94] Note that at frequency zero, the GMM and 2SLS tests are equivalent.

Table 2.5 Test for Codependence – Eurozone Accession Candidates

			Codependence of order							
			0		1		2		3	
	Lags	Null	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
BGR	7	GMM	46.26	0.000	39.02	0.001	32.24	0.006	24.79	0.053
		2SLS			28.59	0.018	26.41	0.034	13.07	0.597
ROU	5	GMM	72.60	0.000	56.05	0.000	44.22	0.000	32.63	0.000
		2SLS			34.80	0.000	33.56	0.000	12.63	0.180
HRV	6	GMM	31.70	0.002	27.26	0.007	24.67	0.016	19.12	0.086
		2SLS			18.75	0.095	16.59	0.166	9.94	0.621
HUN	6	GMM	43.42	0.000	34.26	0.000	28.20	0.003	16.08	0.138
		2SLS			21.14	0.032	19.93	0.046	7.73	0.737
POL	5	GMM	77.16	0.000	62.86	0.000	45.12	0.000	28.88	0.002
		2SLS			42.15	0.000	39.28	0.000	11.66	0.390
CZE	5	GMM	19.35	0.022	10.41	0.319	5.92	0.747	4.75	0.855
		2SLS			7.61	0.574	7.60	0.575	2.70	0.975
SWE	7	GMM	17.24	0.244	12.85	0.538	9.82	0.775	10.11	0.754
		2SLS			9.75	0.780	7.60	0.909	7.77	0.901

Note: Table 2.5 reports optimal GMM and 2SLS $\chi 2$ test statistics and relative p-values. Optimal lag order is derived from the Akaike Information Criterion.

2.5.3.3 Robustness Analysis

To further explore the robustness of the limited finding on a common seasonal pattern, we first consider the choice of lag length in the common features test. In our baseline specification, the lag length was determined by the Akaike Information Criterion (AIC). However, the underspecification of the lag length might lead to an overly easy rejection of the null hypothesis of "no common serial correlation feature" as any remaining autocorrelation in the residuals would be picked up in the second stage of the test. We therefore also explored other lag structures to illustrate this point. Table 2.6 shows the results when adding or dropping one lag, compared to the one indicated by the AIC.

Table 2.6 Sensitivity to Lag Choice – Eurozone Accession Candidates

	Cointegration at Frequency	Lags	Null	Codependence of order 0		1		2		3	
				Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
BGR	0, π	6	GMM	47.21	0.000	35.16	0.001	32.28	0.002	21.92	0.057
			2SLS			26.53	0.014	23.16	0.040	12.84	0.461
	0, π	8	GMM	45.98	0.000	38.32	0.002	31.74	0.016	26.98	0.058
			2SLS			28.85	0.036	26.83	0.061	13.92	0.673
ROU	π	4	GMM	77.31	0.000	58.56	0.000	45.49	0.000	31.58	0.000
			2SLS			36.98	0.000	32.35	0.000	12.71	0.122
	π	6	GMM	69.74	0.000	55.73	0.000	45.48	0.000	31.66	0.002
			2SLS			34.95	0.000	33.70	0.001	13.33	0.345
HRV	0	5	GMM	31.46	0.000	24.88	0.006	21.01	0.021	18.51	0.047
			2SLS			15.95	0.101	16.67	0.082	10.12	0.430
	0, π	7	GMM	32.71	0.005	28.28	0.020	24.47	0.058	18.06	0.260
			2SLS			20.02	0.171	19.07	0.211	8.97	0.879
HUN	-	5	GMM	42.75	0.000	33.33	0.000	26.38	0.002	17.09	0.047
			2SLS			21.65	0.010	20.44	0.015	8.74	0.461
	-	7	GMM	42.33	0.000	34.07	0.001	25.18	0.022	14.69	0.327
			2SLS			21.23	0.069	17.64	0.172	7.32	0.885
POL	0, π	4	GMM	74.44	0.000	67.22	0.000	47.56	0.000	30.29	0.000
			2SLS			45.40	0.000	41.23	0.000	12.89	0.168
	0, π	6	GMM	72.04	0.000	59.98	0.000	40.98	0.000	28.88	0.007
			2SLS			42.75	0.000	39.03	0.000	13.96	0.376
CZE	-	4	GMM	20.06	0.005	10.11	0.183	5.40	0.611	4.18	0.759
			2SLS			7.02	0.427	6.67	0.464	2.61	0.918
	-	6	GMM	18.64	0.068	10.40	0.495	6.20	0.859	4.99	0.932
			2SLS			7.54	0.754	8.00	0.713	3.04	0.990
SWE	-	6	GMM	19.48	0.053	13.13	0.285	9.54	0.572	6.36	0.849
			2SLS			9.36	0.588	6.75	0.819	5.61	0.898
	0	8	GMM	16.64	0.410	12.80	0.687	12.34	0.720	12.42	0.714
			2SLS			10.09	0.862	9.44	0.894	9.30	0.901

Note: Table 2.6 reports optimal GMM and 2SLS χ2-tests including p-1 or p+1 lags, with p being the lag order of the benchmark specification reported in Table 2.5.

We indeed find that with a shorter lag length, an even stronger rejection of the null hypothesis occurs, while at a larger lag length, we no longer reject a common serial correlation feature for the case of the Czech Republic at the conventional 5% significance level, when using the 2SLS procedure, which leads to a p-value of 0.068. We nevertheless keep the AIC as our benchmark. This is because the alternative Schwarz Information Criterion (SIC) indicates the same, or fewer lags to be included in the exercise. Also, when using the 10% level, the result of the Czech Republic would be negative, and the GMM test even rejects the common feature at 5%.

Table 2.7 reports the results of the earlier canonical correlation-based version of the common features test of Tiao and Tsay (1989) as another robustness check, of which the previously reported test can be seen as a generalization. Schleicher (2007) showed that the optimal GMM estimator tends to slightly under-reject and the Tiao and Tsay test tends to slightly over-reject at sample sizes comparable to those in our analysis. When using this test, however, we confirm most of the findings above, except for Sweden, which according to the strict common features test, does not constitute an optimal currency area with the EMU countries.

All in all, the evidence of common persistence and the similarity of autoregressive coefficients between the EU12 and the acceding countries is very weak. The case of Sweden, for which we have conflicting results from different testing procedures, remains ambiguous.

Table 2.7 Tiao and Tsay Codependence Test – Eurozone Accession Candidates

	Cointegration at Frequency	Lags	Null	Codependence of order 0		1		2		3	
				Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
BGR	0, π	7	k=1	103.83	0.000	25.03	0.050	15.54	0.413	7.23	0.951
			k=2	261.64	0.000	55.50	0.006	35.35	0.313	23.37	0.866
ROU	-	5	k=1	98.02	0.000	22.34	0.008	10.40	0.319	7.37	0.598
			k=2	233.32	0.000	46.76	0.001	25.75	0.174	18.18	0.576
HRV	0	6	k=1	86.83	0.000	22.77	0.030	11.77	0.464	5.27	0.948
			k=2	224.71	0.000	48.58	0.005	29.46	0.291	19.66	0.807
HUN	-	6	k=1	109.03	0.000	21.96	0.025	11.56	0.398	5.17	0.923
			k=2	271.91	0.000	49.44	0.002	29.36	0.207	18.70	0.768
POL	0, π	5	k=1	81.76	0.000	25.32	0.008	13.41	0.267	5.59	0.899
			k=2	222.88	0.000	53.64	0.000	39.32	0.025	26.10	0.348
CZE	-	5	k=1	74.31	0.000	16.64	0.055	8.34	0.501	4.07	0.907
			k=2	211.36	0.000	39.31	0.006	20.52	0.426	10.38	0.961
SWE	0	7	k=1	74.98	0.000	23.60	0.051	10.58	0.719	5.76	0.972
			k=2	217.92	0.000	55.07	0.003	34.64	0.256	26.65	0.641

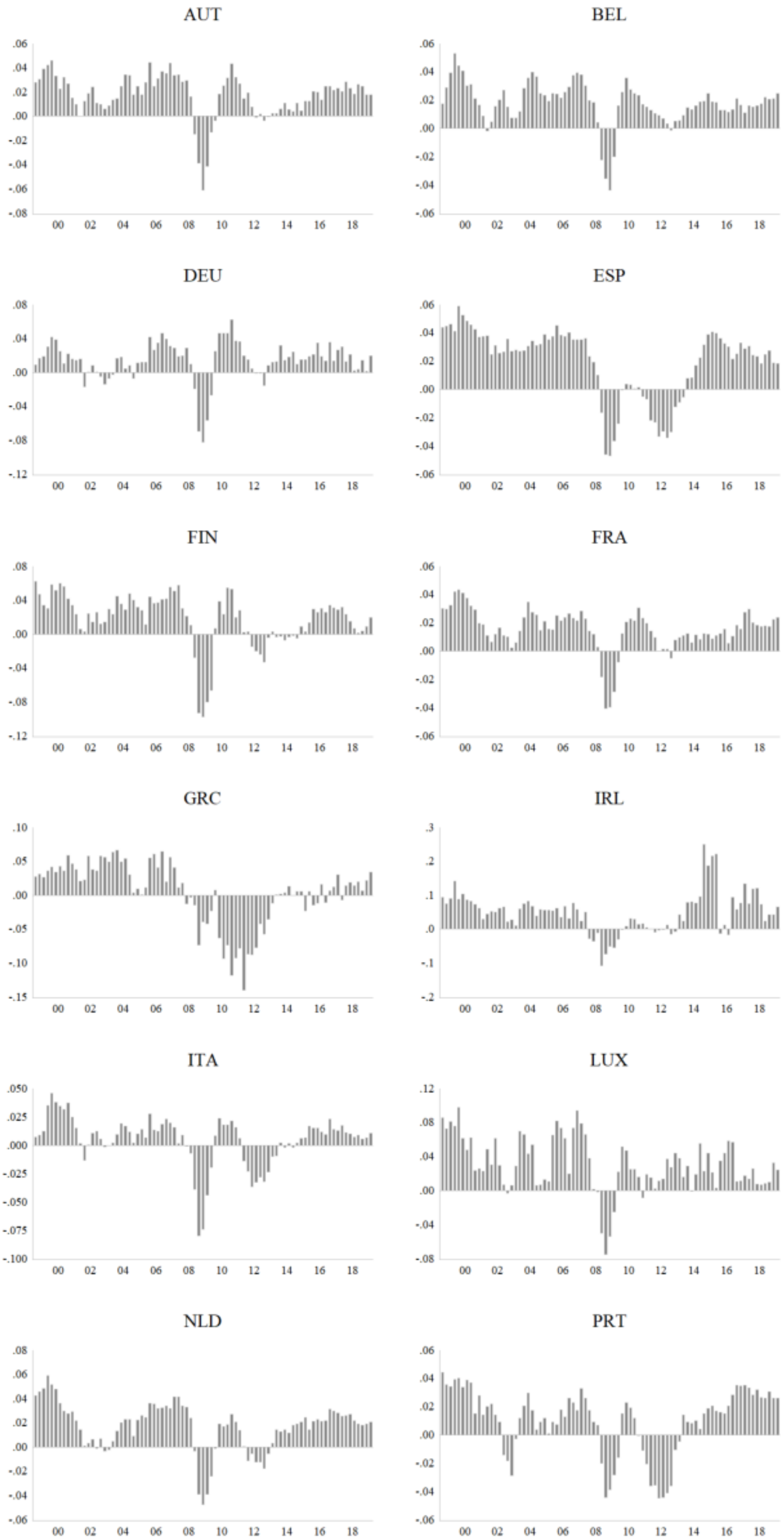
Notes: Table 2.7 reports Tiao and Tsay (1989) test statistics and relative p-values. Optimal lag order between 1 and 7 is derived by Akaike Information Criterion of the bivariate VAR incl. deterministic trends and seasonal dummies.

2.5.3.4 Comparison to Euro Area Member Countries

The previous section examined whether the acceding countries individually share a common business cycle with the EA12 aggregate. In this section, I examine whether euro area members share a common business cycle with other members. The aggregate of the other euro countries is formed by adding the individual countries, excluding the country under investigation from the aggregate.

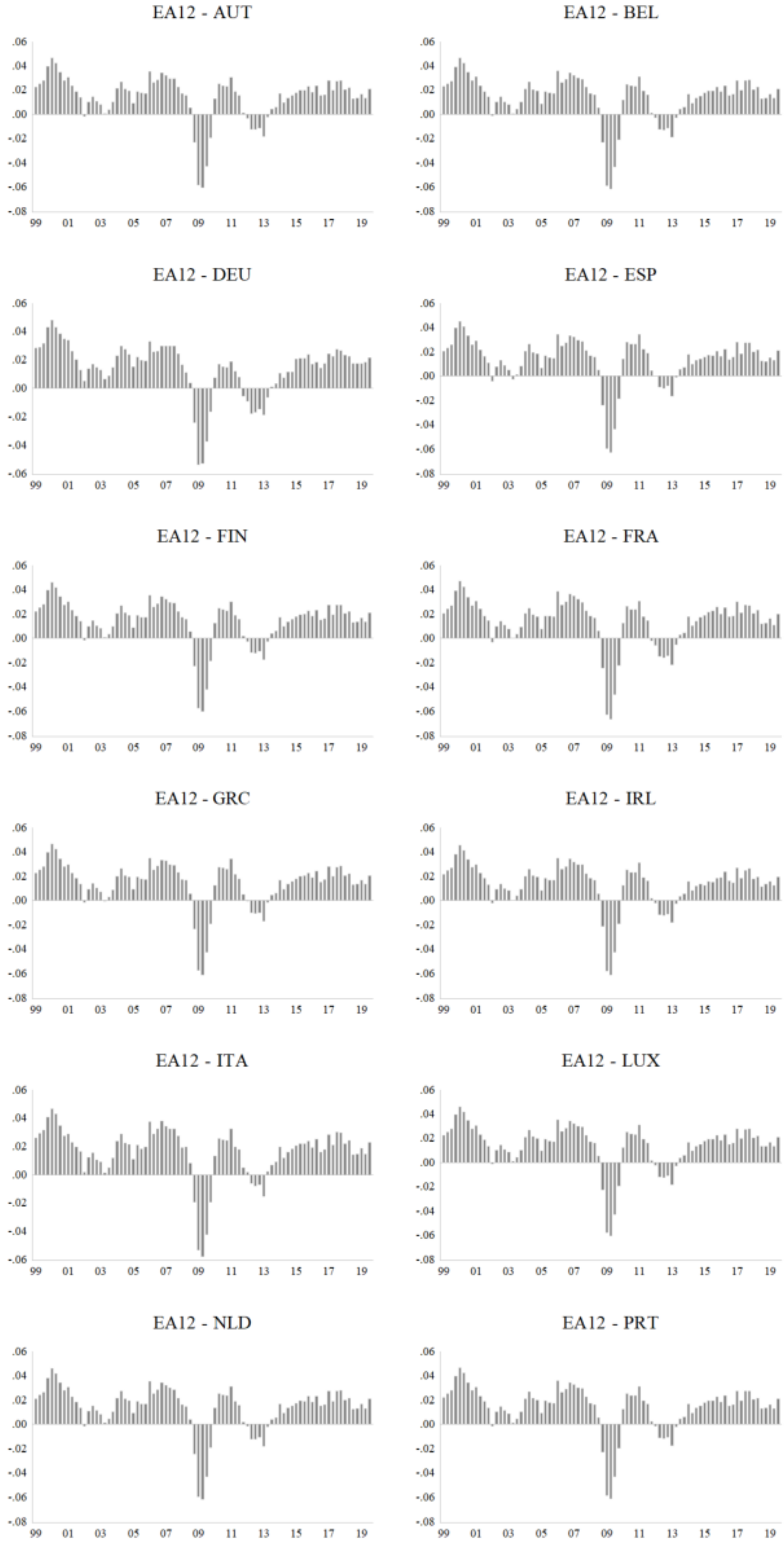
Figure 2.4 displays the logged seasonal growth rates of the seasonally unadjusted real GDP of the individual countries. The euro area aggregate, EA12, minus the respective countries GDP is shown in Figure 2.5.

Figure 2.4 Real GDP Growth Rates – Eurozone Members



Note: Figure 2.4 depicts seasonal growth rates of real GDP (not seasonally adjusted) from 1991Q1 until 2019Q3 for Austria (AUT), Belgium (BEL), Germany (DEU), Spain (ESP), Finland (FIN), France (FRA), Greece (GRC), Ireland (IRL), Italy (ITA), Luxembourg (LUX), the Netherlands (NLD), and Portugal (PRT).

Figure 2.5 Real GDP Growth Rates – Aggregate: Eurozone Members



Note: Figure 2.5 depicts seasonal growth rates of real GDP (not seasonally adjusted) from 1991Q1 until 2019Q3 for the euro area aggregate (EA12) less the GDP of the individual country (Austria (AUT), Belgium (BEL), Germany (DEU), Spain (ESP), Finland (FIN), France (FRA), Greece (GRC), Ireland (IRL), Italy (ITA), Luxembourg (LUX), the Netherlands (NLD), and Portugal (PRT)).

Comparing these for the individual countries, as with the countries among each other, reveals predominantly commonalities. Again, we see the boom period in the mid-2000s and negative growth rates in the wake of the global financial crisis, followed by a rebound and a renewed crisis, which have differing impacts on the various countries. The sample again includes the period from 1999Q1 to 2019Q3 and the data is extracted from Eurostat.

The estimation of formal correlation coefficients confirms the impression from the visual inspection. They reveal a sizable and statistically significant degree of correlations between the growth rates of the individual countries and the euro area aggregate. The coefficients are reported in Table 2.8.

Table 2.8 Correlation Coefficients – Eurozone Members

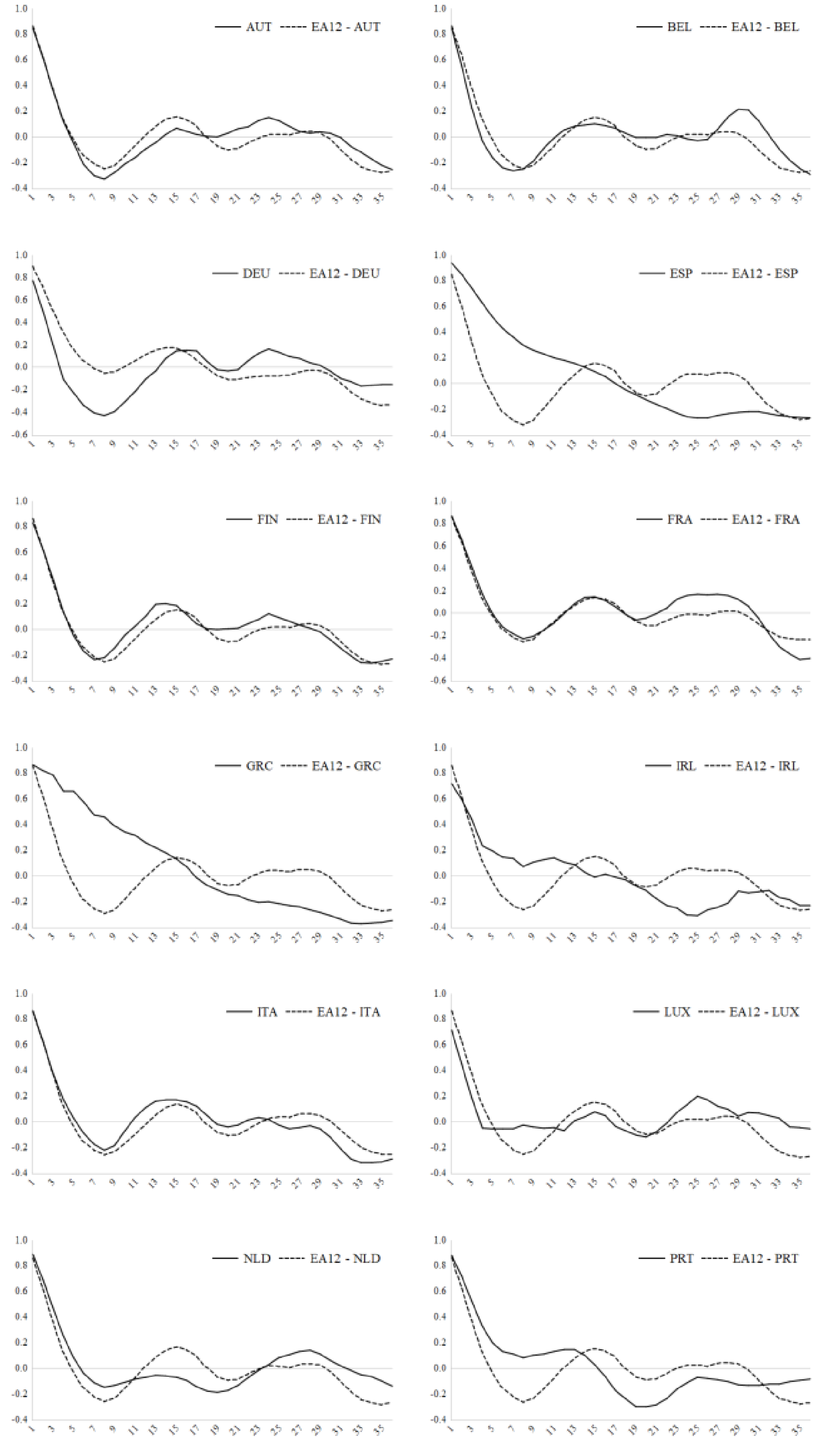
	Austria	Belgium	Germany	Spain
EA12 – individual country	0.938***	0.955***	0.813***	0.897***
	Finland	France	Greece	Ireland
EA12 – individual country	0.792***	0.925***	0.619***	0.404***
	Italy	Luxembourg	Netherlands	Portugal
EA12 – individual country	0.971***	0.643***	0.928***	0.904***

Notes: Table 2.8 reports (Pearson) correlation coefficients between countries' real GDP (seasonal) growth rates. *, **, *** indicate statistical significance at 10%, 5%, and 1%.

To gain an impression of the persistence, the autocorrelation functions of each time series in comparison to the euro area aggregate (minus the respective country) are displayed in Figure 2.6. The cyclical response patterns of each country to exogenous shocks in comparison to those of the aggregate look quite similar for most of the countries. Larger deviations can be observed for Spain, Greece, and Ireland. The correlograms of the different aggregates do not differ much from each other. For Germany, for example, however, the autocorrelation function is negative for much fewer periods following the initial positive autocorrelation.

The prerequisites for the estimation of the common features tests, the HEGY seasonal unit root test, and the seasonal cointegration test are displayed in Appendix II, Table A2.1 and Table A2.2. The log-level series of all countries (except France and Germany) are integrated at frequency zero and stationary at all other frequencies, except for Greece and Ireland, that are integrated at frequency π, and France and Germany, which are stationary at frequency zero. We consider these stationarity properties when testing for cointegration in the next step. Only real GDP of Germany and the Netherlands are cointegrated with that auf the euro area aggregate and thus share a common long-term trend with the EA12.

Figure 2.6 Autocorrelograms – Eurozone Members



Note: Figure 2.6 shows estimated sample autocorrelation functions of real GDP growth rates (seasonal differences of logarithmized values) over 36 quarters.

The results of the test for common cycles are reported in Table 2.9. As in Section 2.5.3.2, the parameters are estimated with 2SLS and GMM. The Codependence of order zero captures the case of identical impulse response patterns, and the null hypothesis of no common cycles can be rejected for Austria, Germany, Finland, France, Italy, and the Netherlands. This suits the earlier literature summarized in chapter 2.5.2. No evidence exists for a perfectly common feature in Belgium, Greece, Ireland, Luxembourg, and Portugal. Comparing this result with the correlograms, it is a little puzzling for Belgium, whose autocorrelation function is quite similar to the aggregate.

Considering a weaker definition and allowing for an initially different reaction, codependence of order one, the null hypothesis cannot be rejected for Greece, Ireland, Luxembourg, and Portugal. Regarding higher orders of codependence, even more evidence exists for common cyclical elements.[95] Overall, there is much more evidence for common cycles among the members of the European Monetary Union than for the acceding countries to the euro area which could support the endogeneity hypothesis by Frankel and Rose (1997), as there are studies that could not find evidence for common business cycles for the euro countries before the introduction of the common currency.

However, optimal currency areas are not solely a topic of discussion in Europe. In the economic literature, there are also discussions on this topic in Asia, which have increased with the rise of China and the RMB. In the next section, I first provide information on the institutional background and then also conduct an empirical analysis for China and 10 East and Southeast Asian countries.

[95] The results are verified using the canonical correlation-based test proposed by Tiao and Tsay (1989), reported in A2.3 in Appendix II. According to this test, none of these countries shares a perfectly synchronous cycle with the euro area aggregate. However, at higher orders of codependence, evidence exists for common cyclical elements for all countries.

Table 2.9 Test for Codependence – Eurozone Members

			Codependence of order							
			0		1		2		3	
Country	Lags	Null	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
		GMM			9.420	0.583	7.845	0.727	5.448	0.908
Austria	6	2SLS	13.989	0.234	10.629	0.475	9.365	0.588	7.117	0.790
		GMM			13.003	0.162	13.027	0.161	4.226	0.896
Belgium	5	2SLS	22.483	0.007	18.045	0.035	14.776	0.097	7.369	0.599
		GMM			11.734	0.628	9.884	0.771	5.360	0.978
Germany	7	2SLS	22.009	0.078	20.386	0.118	18.809	0.172	17.274	0.242
		GMM			15.630	0.075	14.616	0.102	7.177	0.619
Spain	5	2SLS	33.184	0.000	22.140	0.008	16.507	0.057	15.461	0.079
		GMM			6.255	0.856	6.271	0.855	4.543	0.951
Finland	6	2SLS	7.377	0.768	6.229	0.858	5.804	0.886	4.397	0.957
		GMM			4.342	0.959	3.822	0.975	2.116	0.998
France	6	2SLS	9.101	0.613	6.119	0.865	5.155	0.923	3.871	0.974
		GMM			39.261	0.000	34.619	0.010	16.479	0.224
Greece	7	2SLS	87.557	0.000	66.689	0.000	49.431	0.000	36.013	0.001
		GMM			33.355	0.001	29.631	0.003	11.240	0.508
Ireland	6	2SLS	65.570	0.000	34.720	0.001	24.564	0.017	9.828	0.631
		GMM			3.430	0.984	2.317	0.997	0.914	1.000
Italy	6	2SLS	4.974	0.932	2.654	0.995	1.910	0.999	0.555	1.000
		GMM			35.665	0.000	34.620	0.000	18.667	0.028
Luxembourg	5	2SLS	54.875	0.000	42.952	0.000	37.642	0.000	30.563	0.000
		GMM			7.192	0.845	5.107	0.954	3.240	0.994
Netherlands	6	2SLS	12.290	0.423	10.936	0.534	9.620	0.649	8.894	0.712
		GMM			22.714	0.045	16.008	0.249	8.597	0.803
Portugal	7	2SLS	40.549	0.000	34.373	0.001	23.815	0.033	17.779	0.166

Note: Table 2.9 reports optimal GMM and 2SLS $\chi 2$ test statistics and relative p-values. Optimal lag order is derived from the Akaike Information Criterion.

2.6 A Renminbi Bloc

2.6.1 Institutional Background

Several causes exist for greater monetary cooperation in East Asia and the focus on the RMB, which is gradually taking center stage as an anchor currency; these can be summarized in two main aspects. The first is the diminishing influence of the U.S. dollar following the Asian crisis, while the second is the closer relationship with China, especially based on greater trade integration, and the now strong and independent international role of the RMB.

In response to the Asian financial crisis in 1997/8, many fixed exchange rate regimes that previously existed between Asian currencies considered in this study and the U.S. dollar were dissolved. By now, the Philippines, Japan, Thailand, Korea and Indonesia have established flexible exchange rate systems, while Taiwan, Singapore, Malaysia and China use managed floating exchange rate regimes. Hong Kong maintains its fixed exchange rate regime with the U.S. dollar, managed by a currency board. The Macau pataca is pegged to the Hong Kong dollar and thus also indirectly to the U.S. dollar. A graphical representation of the different current exchange rate regimes is shown in Panel A of Figure 2.7.[96]

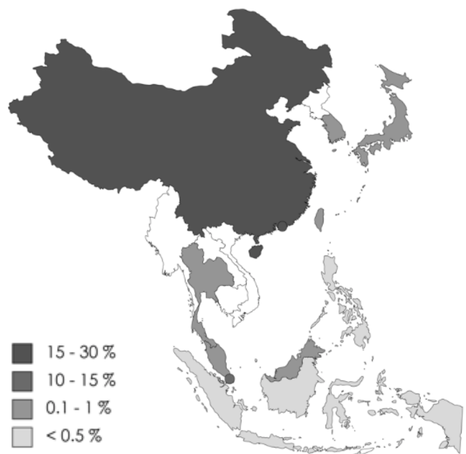
When examining bilateral trade, it also becomes clear that the United States are not the most important trading partner for the East Asian countries considered in this study. Figure 2.8 reveals that for each country, the bilateral trade with the United States as a share of total trade of the country is lower than the bilateral trade with China. Although the influence of the U.S. dollar is declining in terms of exchange rate management and bilateral trade, it has maintained its strong position on the foreign exchange market; the U.S. dollar remains the most actively traded currency worldwide (Bank for International Settlements, 2019).

[96] More detailed information on exchange rate regimes is reported in the International Monetary Fund's Annual Report on Exchange Rate Arrangements and Exchange Restrictions (AREAER).

Figure 2.7 Financial and Trade Integration in East Asia

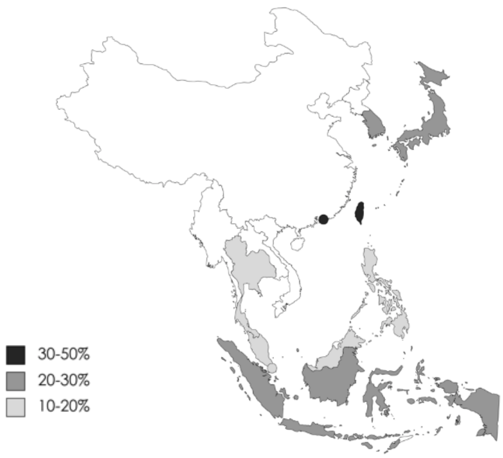
Panel A: Exchange Rate Regimes

Panel B: Share of RMB Foreign Exchange Trading



Panel C: Policy Measures to Promote the International Use of the RMB

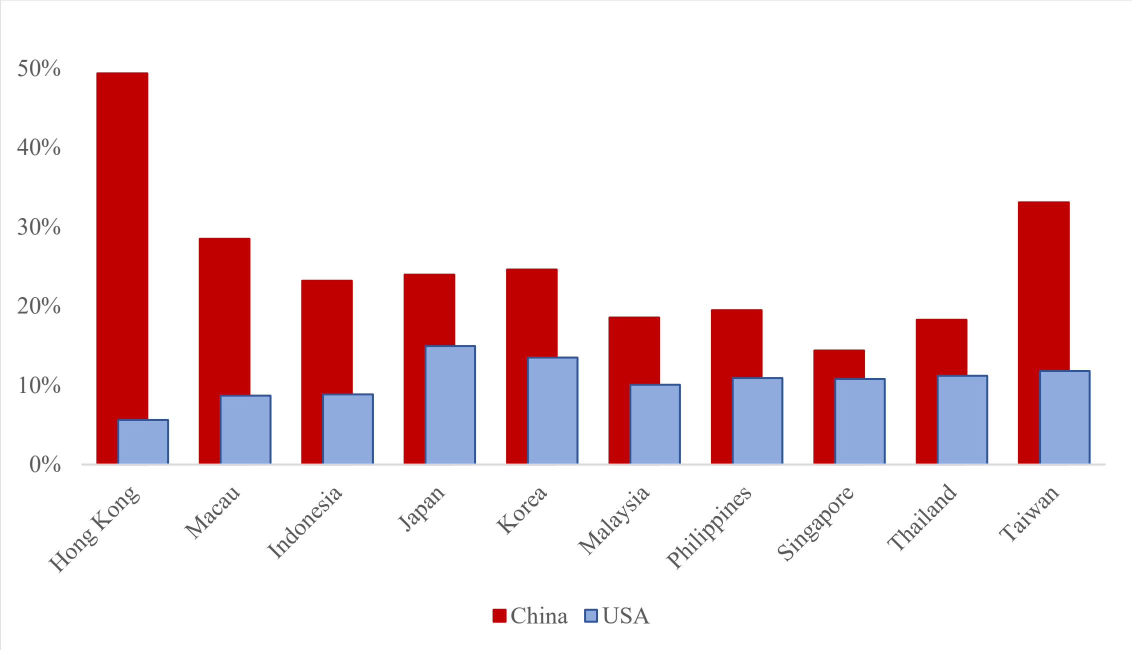
Panel D: Share of Bilateral Trade with China



Notes: Information on exchange rate regimes is retrieved from IMF AREAER Database and from country monetary authorities. Information on the dissemination of policy measures are from news from SAFE and Peoples Bank of China. Foreign exchange data is from the BIS Triennial Survey on Foreign Exchange Turnover 2019. Bilateral trade data is from the IMF DOTS database. The map was created with mapchart.net. Countries colored in white are shown for better geographical overview.

A closer relationship with China and within East Asia has been fostered by the introduction of various initiatives to facilitate greater integration in the region following the Asian crisis. For instance, several institutions for policy coordination were established: the ASEAN+3 forum was founded in December 1997. Furthermore, the Chiang Mai Initiative was introduced in 2002 as a safety net of first bilateral, then multilateral, swap agreements. In addition, ASEAN countries and China recently signed a Regional Comprehensive Economic Partnership.

Figure 2.8 Bilateral Trade with China and the United States in 2020

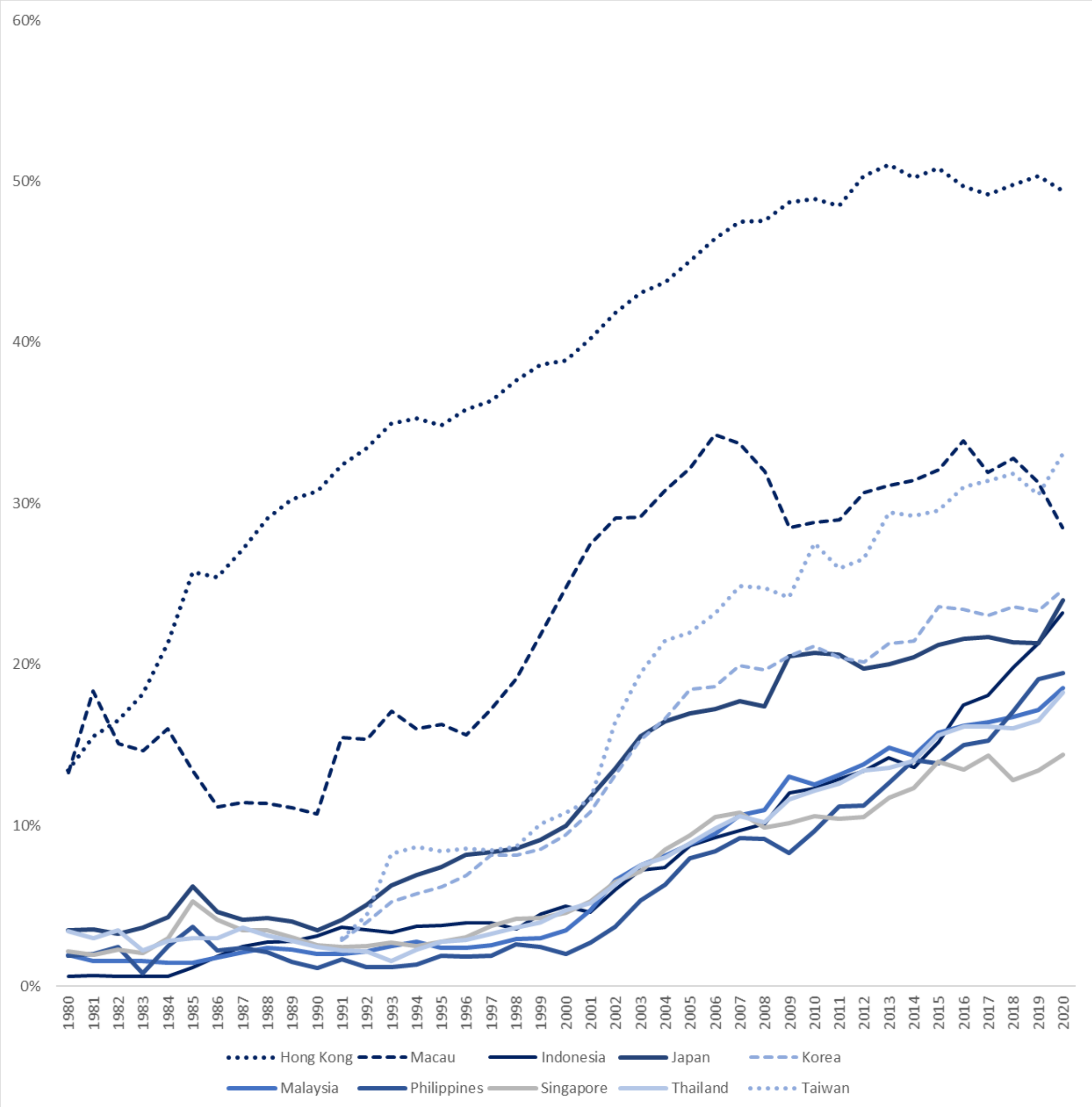


Notes: The graph shows the share of trade (exports + imports) of the East Asian country with China (United States) in relation to the trade of this country with the world (data: IMF dots).

The turn toward China is particularly evident in bilateral trade. Figure 2.9 demonstrates that China has become an increasingly important trade partner for East Asian countries over the last 40 years. In 2020, bilateral trade with China accounted for nearly 50% of Hong Kong's trade and around 30% of Taiwan's and Macau's. A geographical overview of the countries' bilateral trade with China is shown in Panel D of Figure 2.7. Free trade agreements facilitate trade between China and Hong Kong, Singapore, Taiwan, and Macau, as well as between ASEAN and China. Furthermore, the Belt and Road Initiative contributes to the stronger connection between the countries. Since 2013, China has been reaching agreements with countries in Asia, Africa, and Europe. With the exception of Japan, all of the East Asian countries considered in this study are part of this campaign.[97]

[97] See Sun and Hou (2019) and Cai (2020) for an analysis of the feasibility of an OCA with China for Belt and Road Initiative-participating countries.

Figure 2.9 Bilateral Trade with China Over Time



Notes: The graph shows the share of trade (exports + imports) of the East Asian country with China in relation to the trade of this country with the world (data: IMF dots).

In international financial markets, the RMB, is becoming one of the most important. The RMB is now the fourth most actively traded currency worldwide after the US dollar, euro, and British pound. It reached this place for the first time after the announcement of the exchange rate reform in August 2015. This is remarkable, considering that three years earlier, in August 2012, the RMB ranked 12th, and in October 2011, 17th (SWIFT, 2011, 2015a).[98,99] Other indicators of the RMB's growing

[98] Liu et al. (2022) analyze SWIFT data in a network analysis based on a VAR framework and state that in the ASEAN+3 region in particular, the RMB already plays a major role and records large spillovers to local financial systems. In terms of global markets, however, the USD remains the primary actor.

[99] Data from the BIS Triennial Surveys on Foreign Exchange Turnover also shows the increasing

international standing are the inclusion in the SDR currency basket in 2016 and the development of the RMB Globalization Index, which reached the highest level to date in January 2022.[100]

Within the set of countries considered, most RMB trading occurs in Hong Kong (Bank for International Settlements, 2019). This is unsurprising because Hong Kong was the first offshore market to launch RMB trading in 2004. It is followed by Singapore and Taiwan. A graphical presentation of the share of RMB trading of each country included in this analysis is shown in Panel B of Figure 2.7, and an overview of the usage of the RMB in the East Asian countries' foreign exchange markets considered in this study is given in Table 2.10.

Finally, China has introduced a number of policy measures to facilitate the use of the RMB that have contributed to RMB internationalization.[101] These measures include the introduction of the RQFII quota, the establishment of offshore RMB clearing banks, and the conclusion of swap agreements. Of the countries considered in this analysis, Hong Kong, Korea, Malaysia, Singapore, and Thailand have agreed to RQFII quotas with China. However, the investment quota was removed in 2020 to facilitate foreign investors' participation in China's financial market (State Administration of Foreign Exchange, 2020). A swap line agreement has also been implemented with all countries except for the Philippines, while clearing banks have been introduced in all countries included in this study, except for Indonesia and Japan.[102] Panel C of Figure 2.7 shows the

worldwide diffusion. The global share of RMB average daily turnover was 4.32% and 285,030 million USD in April 2019. In 2016 and 2013, the RMB's share was 3.99% and 2.23%, respectively. This is considerably more than in 2010, when RMB trading accounted only for 0.86% of total trading (BIS, 2010, 2013, 2016, 2019).

[100] The Renminbi Globalization Index, published by the Standard Chartered Bank, provides information about RMB activity across key centers (Hong Kong, Singapore, London, Taiwan, New York, Seoul and Paris). The index was launched in November 2012 and includes five parameters: (i) offshore RMB deposits outstanding, (ii) trade settlement and other international payment, (iii) outstanding issues of dim sum bonds and certificates of deposits, (iv) RMB foreign exchange turnover across specific markets, and (v) foreign holdings of onshore assets. The last component was added in September 2017 to cover foreign investors' growing access to China's onshore markets (Standard Chartered Bank, 2019).

[101] The results of empirical studies regarding the effectiveness of the policy measures are mixed. Bilateral trade, financial linkages and the Belt and Road Initiative were identified as other drivers. See, for example, Cheung and Yiu (2017), Cheung et al. (2019), Cai (2020), Chey and Hsu (2020), Park and An (2020), Cheung et al. (2021), and Li et al. (2022).

[102] Which factors force countries to introduce RMB internationalization infrastructure has also been tested empirically. These include holding RMB reserves or a trade agreement, having more developed financial markets and territorial disputes (Liao and McDowell, 2015; Chey et al., 2019).

existence of swap line agreements and RMB clearing banks as of March 2022.

Table 2.10 RMB Foreign Exchange Trading in the Asian Region in 2019

Country	**RMB avg. daily FX turnover**	**Share of RMB trading**	**Rank by amount of RMB trade**	**Most traded currencies (more than RMB)**	**Subsequent position of the RMB**
Hong Kong	107,615	29.78%	1	USD, HKD	3
China	101,226	28.01%	2	USD	2
Singapore	42,565	11.78%	4	USD, JPY, EUR, AUD, SGD, GBP	7
Taiwan	3,655	1.01%	7	USD, TWD, EUR	4
Japan	3,220	0.89%	8	JPY, USD, EUR, AUD, GBP, NZD, CAD, CHF, ZAR	10
Korea	3,125	0.86%	9	USD, KRW	3
Malaysia	241	0.07%	16	USD, EUR, SGD, GBP, AUD, HKD, JPY	8
Indonesia	101	0.03%	22	USD, SGD, EUR, GBP, AUD, JPY	7
Thailand	177	0.05%	19	USD, EUR, JPY, GPB	5
Philippines	40	0.01%	27	USD, JPY, EUR, AUD, GBP, SGD, HKD	8
Total RMB	361,390	4.35%		USD, EUR, JPY, GBP, CAD, CHF	7

Notes: The average daily turnover is reported in USD millions. The share of RBM trading is the share of the trading venue in the respective country in global RMB trading. The rank represents the rank of a country according to its share in RMB trade. All countries that reported data on RMB trade in the BIS 2019 Triennial Survey were included in the ranking. The position of the RMB is derived from all currencies considered individually in the BIS survey. These are: Australian dollar (AUD); Brazilian real (BRL), Canadian dollar (CAD), Swiss franc (CHF), Chinese renminbi (RMB), Danish krone (DKK), euro (EUR), British pound (GBP), Hong Kong dollar (HKD), Hungarian forinth (HUF), Indonesian rupiah (INR), Japanese yen (JPY), Korean won (KRW), Mexican peso (MXN), Norwegian krone (NOK), New Zealand dollar (NZD), Polish zloty (PLN), Russian ruble (RUB), Swedish krona (SEK), Singapore dollar (SGD), Turkish lira (TRY), Taiwan dollar (TWD), United States dollar (USD), South African rand (ZAR). For total RMB the share represents the share of the RMB in global FX trading.

2.6.2 Literature Review

The dominant role of the U.S. dollar and the emerging role of the RMB as an anchor currency have been analyzed empirically by a number of studies. One stand of the literature builds upon a method initially developed by Frankel and Wei (1994) and investigates the influence of the RMB on the implicit or explicit currency basket of Asian countries. This approach has been further developed by Fratzscher and Mehl (2014) and Kawai und Pontines (2016). In this approach, the movement of a country's exchange rate depends on the movements of international currencies, and the estimated coefficients are widely interpreted as the extent of the influence (or co-movements of currencies) of each currency. Overall, the results reveal an increasing influence of the RMB over time on currencies in the Asian region, as well as globally, but to a lesser extent (see, for example, Kawai und Pontines, 2016; Ito, 2017; McCauley and Shu, 2019; Xu and Kinkyo, 2019; Cai, 2020; Chiappini and Lahet, 2020; and Park and An, 2020). Using a Markov switching approach, Keddad (2019) confirms the exchange rate co-movement between the RMB and East Asian currencies. The increasing international spread of the RMB is also supported by Chow (2021) using a connectedness measure and Caporale et al. (2018) using a fractional integration model. In a recent study, Wang et al. (2022) examine exchange rate linkages between the RMB and four ASEAN currencies[103] and find that the now stable linkages have been fostered by various reforms and initiatives to internationalize the RMB and cooperation between countries. Liu et al. (2022) confirm that the RMB has become an influential currency in the Asian region, but this is not confirmed globally.

An additional strand of literature focuses at China's sharp increase in trade volume and examines trade invoicing and effects of policy measures. Not surprisingly, the U.S. dollar still plays a dominant role in invoicing of international trade, while the importance of the RMB is increasing. Georgiadis et al. (2021) analyze the drivers of invoicing and find an increasing effect of introduced swap lines on invoicing in RMB. In this context, Ito and Kawai (2016) also highlight some challenges for China due to low

[103] The four ASEAN currencies under consideration are the Malaysia ringgit, the Thai baht, the Philippine peso, and the Indonesian rupiah.

per capita income, limited financial openness, and the still important role of the U.S. dollar in Asia.

In another strand of the literature, several studies examine the synchronization of business cycles in Asia in the context of optimal currency areas using correlation or cointegration analyses, following Bayoumi and Eichengreen (1993, 1994). Overall, mixed support for synchronized business cycles exists. There is often evidence of commonality between individual countries but not within the larger region (see, among others, Bayoumi et al., 2000; Bacha, 2008; Sato et al., 2009; Sharma and Mishra, 2012; Gong and Kim, 2018. Fidrmuc and Korhonen (2018) present a meta-analysis of Chinese business cycle correlations.

Only two studies examine business cycles for common serial correlation features and thus relate directly to this analysis. Cheung and Yuen (2005) and Sato and Zhang (2006) examine Asian countries in terms of correlated shocks and equal responses to them in the context of a monetary union, using cointegration analysis and common features tests.

Cheung and Yuen (2005) study what is known as Greater China Region, consisting of China, Hong Kong and Taiwan, with respect to a possible currency union. They analyze seasonally adjusted real GDP data from 1994Q1 to 2002Q4. For the cointegration analysis, they use the Johansen test, proposed by Johansen (1991) and Johansen and Juselius (1990), in a multivariate setting. The null hypothesis of no cointegration relationship is rejected, and evidence for a cointegrating vector is shown. This is interpreted as evidence of synchronous long-term movements. The results of the subsequent codependence tests indicate that China, Hong Kong, and Taiwan also share common business cycles.

Sato and Zhang (2006) examine the suitability of a monetary union in East Asia, in a sample from 1978Q1 to 2004Q4, and analyze seasonally adjusted real GDP for the existence of long-term co-movement in a bivariate approach also using the Johansen cointegration test. In addition, they perform a common features test, following Vahid and Engle (1993) and Engle and Kozicki (1993). Sato and Zhang (2006) analyze relationships not only among Asian countries but also with the U.S. and Japan, which could be possible anchor currencies. Cointegration relationships are found between the U.S. and most East Asian countries, as well as some between Japan and East Asian countries. Various cointegration relationships are found among East Asian countries. Furthermore, Taiwan and Hong Kong are cointegrated with China, and a subsequent codependence test reveals common features between Hong Kong and China.

2.6.3 Empirical Analyses – Asia

2.6.3.1 Data and Preliminary Analysis

In this study, quarterly real GDP data from 2000Q1 until 2021Q1 for China and 10 East and Southeast Asian countries[104] from the IMF International Financial Statistics (IFS) database and individual country statistics reporting institutions is analyzed. All GDP data is in logs of millions of RMB.[105]

After a visual inspection of seasonal real GDP growth rates and an estimation of formal correlation coefficients to get a first impression of connections between the individual countries and China, autocorrelation functions are presented that can be interpreted as the cyclical response pattern of each country to an exogenous shock. As the conceptual framework (Section 2.3) implies that not only does the correlation of shocks matter but that persistence of shocks and a common reaction is as important to avoid welfare effects from adopting a common currency in addition to the loss of the flexible exchange rate.

The formal analysis starts with the application of the HEGY seasonal unit root test proposed by Hylleberg et al. (1990). Second, the data is analyzed for cointegration at different seasonal frequencies, following the approach of Lee (1992). Finally, to test for common cycles, the common features test for seasonally cointegrated time series, introduced by Cubadda (1999), is applied, which disentangles trends and cycles from

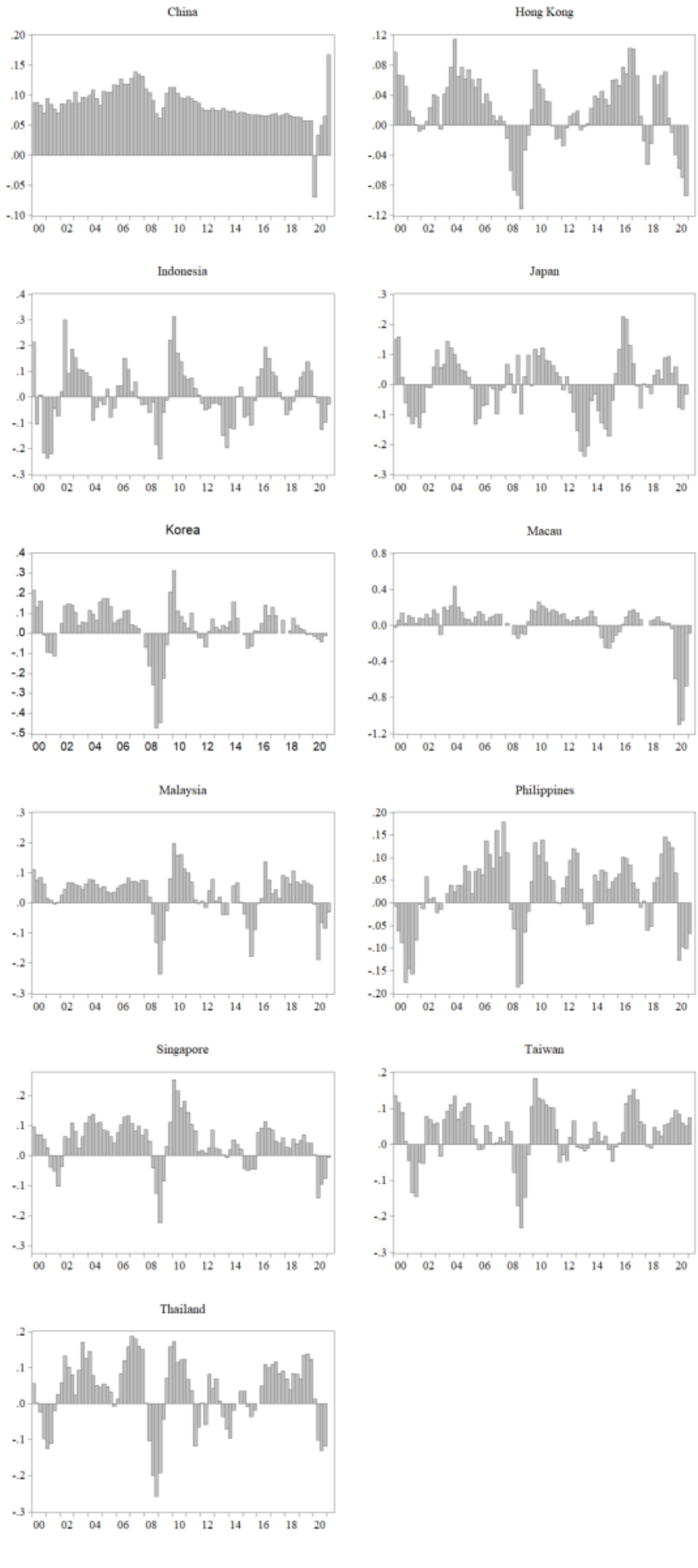
[104] The countries are Japan, Hong Kong, Indonesia, Malaysia, Philippines, Singapore, South Korea, Thailand, Taiwan, and Macau.
[105] Quarter-end exchange rates were extracted from the Pacific Exchange Rate Service.

seasonality.

Eyeballing the real GDP data in Figure 2.10, one can see immediately that the growth rates of China look very different from those of the other countries. For instance, except for the beginning of the COVID-19 pandemic, negative growth rates never occur. For the other East Asian countries, one can see commonalities across countries, including the cyclical downturn and subsequent rebound after the global financial crisis in 2008/9, followed by a rebound. Of course, differences exist in the magnitude of the impact of the global financial crisis and in the impact and timing of the pandemic. However, the first impression is that the growth rates do not support the idea of common cycles.

More formally, correlations between each country's logged real GDP growth rates and China's are estimated. The estimation of correlation coefficients (Table 2.11) reveals mixed results. While the logged GDP growth rates from Hong Kong, Korea, Macau, Malaysia, the Philippines, and Taiwan are each significantly correlated with China's logged GDP growth, Indonesia, Japan, Singapore, and Thailand do not show significant correlation coefficients.

Figure 2.10 Real GDP Growth Rates – East Asian Countries and China



Notes: Figure 2.10 depicts seasonal growth rates of logarithmized real GDP from 2000Q1 to 2021Q1 for China, Hong Kong, Indonesia, Japan, Korea, Macau, Malaysia, Philippines, Singapore, Taiwan and Thailand. Data is from the IMF IFS database and individual country statistics reporting institutions.

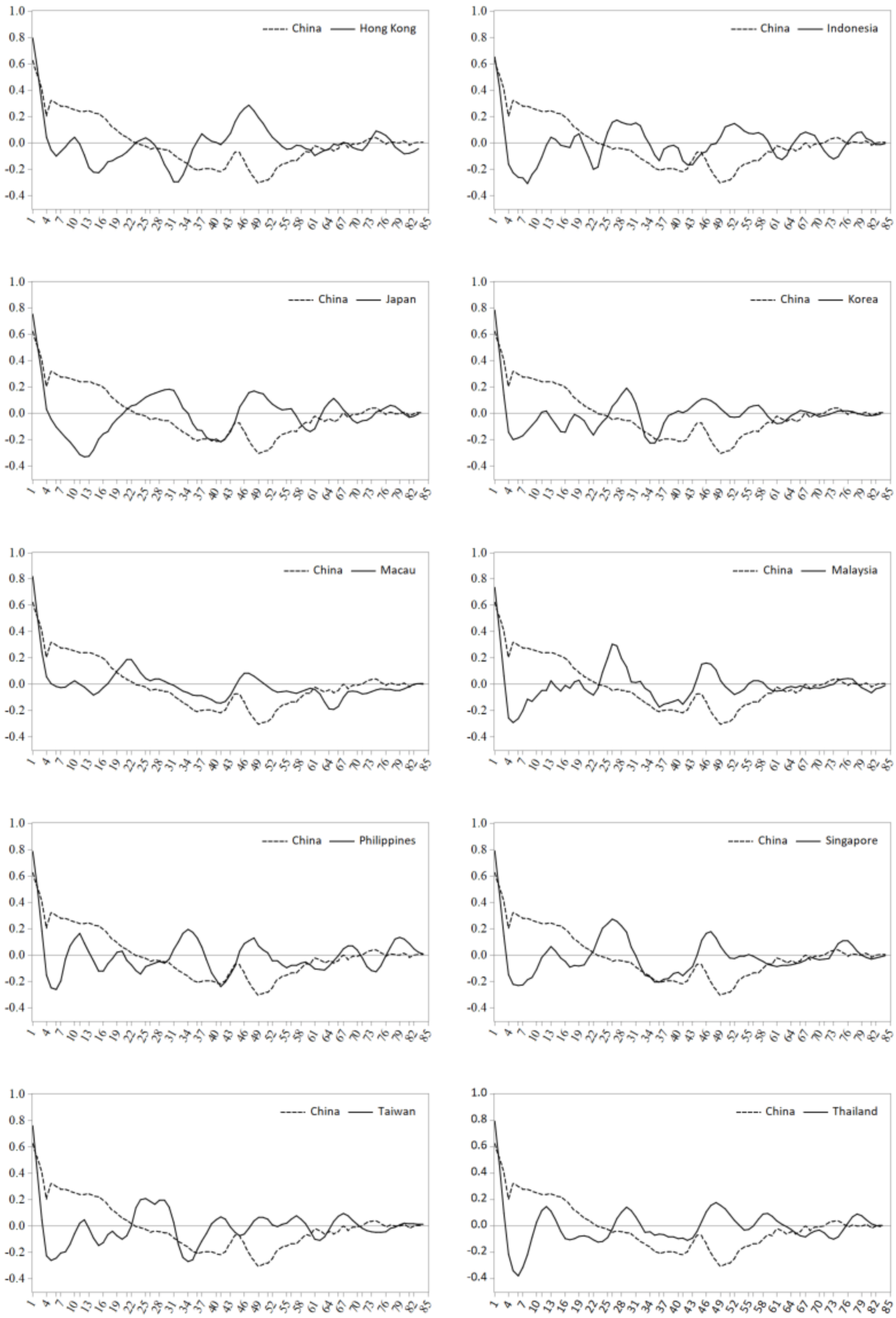
Table 2.11 Correlation Coefficients – East Asian Countries and China

	China	obs
Hong Kong	0.743*** (10.068)	84
Indonesia	-0.009 (0.082)	85
Japan	0.214* (1.989)	84
Korea	0.745*** (10.114)	84
Macau	0.800*** (12.142)	85
Malaysia	0.508*** (5.378)	85
Philippines	0.730*** (9.742)	85
Singapore	0.190 (1.761)	85
Taiwan	0.800*** (12.142)	85
Thailand	0.157 (1.442)	84

Notes: Table 2.11 reports (Pearson) correlation coefficients between countries' real GDP growth rates (first differences). t-statistics for the null of the coefficient being unequal to zero are given in parenthesis. *, **, *** indicate statistical significance at 10%, 5%, and 1% level, respectively. The sample period is 2000Q1-2021Q1.

The next step is the analysis of the persistence of shocks. For each country, the standard response to an exogenous shock is shown in comparison with China. The autocorrelation can be interpreted as the cyclical response pattern of each country to an exogenous shock. Again, the displayed autocorrelation functions look quite different across countries. China's autocorrelation is characterized by a positive autocorrelation for the first 23 quarters, followed by a negative autocorrelation, which becomes positive again after 71 quarters (Figure 2.11).

Figure 2.11 Autocorrelograms – East Asian Countries and China

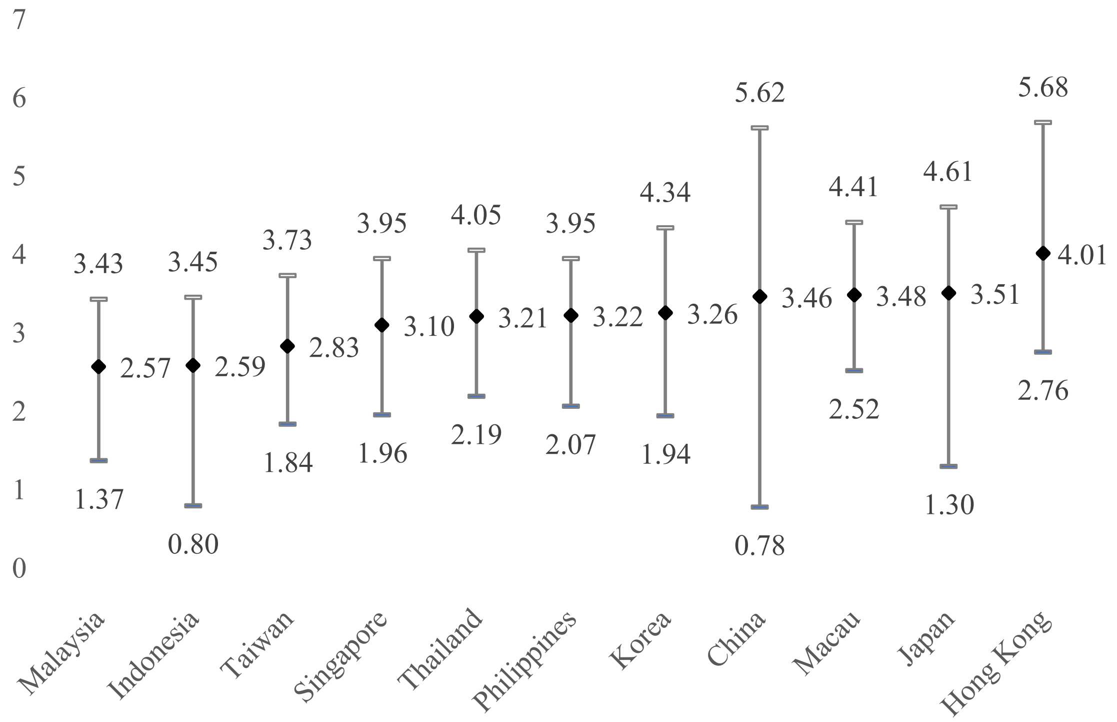


Note: Figure 2.11 shows estimated sample autocorrelation functions of real GDP growth rates (seasonal differences of l logarithmized values) over 84 quarters.

The autocorrelation functions of the other East Asian countries show positive autocorrelations for the first 4 to 5 quarters, negative autocorrelations thereafter, and further ups and downs. The duration of the negative autocorrelation differs among the countries. However, accumulating these impulse response patterns in the GDP growth rates results in the typical up-and-down swing pattern in the associated levels of GDP around its trend. Overall, China seems to have a much longer cycle.

A further non-regression-based, simple method to analyze the persistence of shocks is the estimation of half-lifes. Estimates are reported in Figure 2.12. The point estimates of the 10 East Asian countries and China are quite close to each other. Malaysia exhibits the shortest half-life estimate of 2.57 quarters, and Hong Kong shows the longest half-life estimate of 4.01 quarters. China's half-life estimate of 3.46 quarters lies in between. Thus, although China exhibits longer cycles, the largest part of the mean reversion occurs in a broadly similar time span.

Figure 2.12 Half-life Estimates – East Asian Countries and China



Notes: Figure 2.12 depicts half-life estimates (+/– 2 standard errors) based on the impulse response functions of a vector autoregressive model with 4 lags.

The first step of the formal analysis is the seasonal unit root test by Hylleberg et al. (1990). The results of the analysis of the logged GDP data for unit roots at the zero and seasonal frequencies are reported in Table 2.12. Except for Indonesia and the Philippines, all time series are integrated of order one at the zero frequency. Since log-level data is used, it is plausible to find integrated series at the zero frequency. At the frequencies π and $\frac{\pi}{2}$, all time series are stationary.[106]

Table 2.12 HEGY Unit Root Tests – East Asian Countries and China

	Frequency			
Country	0	PI	PI/2	All seasonal frequencies
Japan	-3.031	-4.010**	14.733***	14.324***
Indonesia	-3.592**	-5.125***	12.761***	22.355***
Malaysia	-2.632	-4.106***	13.674***	11.111***
Philippines	-4.166***	-3.574***	12.591***	12.224***
Singapore	-1.939	-3.969***	19.260***	17.535***
Thailand	-3.137*	-3.539***	8.750***	10.623***
Korea	-2.376	-6.073***	22.516***	30.017***
Hong Kong	-2.447	-4.420***	13.652***	15.457***
Taiwan	-2.264	-4.803***	20.063***	22.614***
Macau	-0.268	-4.492***	10.702***	14.144***
China	0.391	-3.082**	12.061***	9.869***

Note: Table 2.12 shows results from the HEGY seasonal unit root test (see Hylleberg et al., 1990) for log-levels of seasonally unadjusted GDP. Regressors include, intercept, trend, and seasonal dummies. Optimal lag order between 1 and 7 is derived automatically from the Akaike Information Criterion.

The next step is the test for cointegration of the logged GDPs of the individual countries and China, at zero and seasonal frequencies. The results of the seasonal cointegration test are reported in Table 2.13. The optimal lag order for the bivariate VAR is derived from the AIC. The cointegration test reveals that all countries are indeed cointegrated at the zero frequency and share a common long-term trend with China. At frequency π, Japan, Malaysia, Singapore, Thailand, Korea, Hong Kong, and Macau are cointegrated and also share a common stochastic seasonal trend with China.

[106] In this analysis, all countries show unit root at the same zero and seasonal frequencies with China (except Indonesia and Philippines), which is important for the subsequent analysis. Del Barrio Castro et al. (2021) introduce testing for cointegration if time series exhibit different roots.

Table 2.13 Seasonal Cointegration Tests – East Asian Countries and China

	0		π	
	r = 0	r ≤ 1	r = 0	r ≤ 1
Japan	20.643***	6.367	19.555***	0.963
Indonesia	24.392***	8.794		
Malaysia	25.667***	5.742	32.920***	8.103**
Philippines	25.553***	10.426*	-	-
Singapore	29.876***	4.984	30.123***	9.460**
Thailand	21.390***	8.720	13.766***	0.410
Korea	16.720**	6.297	34.690***	0.449
Hong Kong	14.351**	5.794	24.651***	0.491
Taiwan	10.837*	2.363	-	-
Macau	16.035**	3.001	21.503***	3.861

Notes: Table 2.13 shows results from a bivariate (against EA12) seasonal cointegration test for log levels of seasonally unadjusted real GDP. Trace Statistics. *, **, *** indicates the rejection of the null based on linearly interpolated critical values of Lee and Siklos (1995). Optimal lag order between 1 and 7 is derived by Akaike Information Criterion.

2.6.3.2 Codependence and Common Cycles

This section analyzes whether individual Southeast Asian and East Asian countries share a common impulse response pattern to exogenous shocks with China. Table 2.14 summarizes the results of the SCCF test following Cubadda (1999). The results of both the Engle-Granger 2SLS and GMM estimator are reported. The results formally show that, indeed, little evidence exists for similar reactions to shocks between China and other East Asian countries, which continues the visual impression from the previous section.

The codependence of order zero column in Table 2.14 captures the result of identical impulse response patterns; the null hypothesis of codependence of order $q = 0$ is rejected for all countries. This means that no country shares an identical impulse response pattern with China. In addition, in terms of a codependence of order one, both estimators – the GMM and 2SLS – again reject a common but not perfectly synchronized cycle with China for all countries. In terms of a codependence of order two, Korea and Taiwan seem to share common cyclical elements with China (for at least one of the two estimators). At a codependence of order three, Korea and Hong Kong display some similarities with China.

Table 2.14 Test for Codependence – East Asian Countries and China

		Codependence of order							
		0		1		2		3	
	Null	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
	GMM	68.763	0.000	25.907	0.000	8.718	0.013	7.495	0.024
Japan	2SLS			36.451	0.000	14.017	0.001	15.735	0.000
	GMM	108.986	0.000	85.096	0.000	88.733	0.000	50.939	0.000
Indonesia	2SLS			77.798	0.000	55.648	0.000	46.351	0.000
	GMM	64.111	0.000	28.704	0.000	17.086	0.000	6.707	0.035
Malaysia	2SLS			38.313	0.000	28.945	0.000	12.522	0.002
	GMM	50.711	0.000	20.649	0.000	7.164	0.007	8.086	0.004
Philippines	2SLS			25.570	0.000	12.295	0.000	14.773	0.000
	GMM	45.834	0.000	19.569	0.000	6.785	0.034	7.797	0.020
Singapore	2SLS			25.511	0.000	10.688	0.005	14.352	0.001
	GMM	56.815	0.000	23.105	0.000	8.419	0.015	12.640	0.002
Thailand	2SLS			32.941	0.000	13.360	0.001	23.138	0.000
	GMM	66.925	0.000	26.031	0.000	4.896	0.086	1.009	0.604
Korea	2SLS			37.909	0.000	8.419	0.015	2.407	0.300
	GMM	63.596	0.000	24.340	0.000	8.126	0.017	2.006	0.367
Hongkong	2SLS			33.608	0.000	12.967	0.002	5.233	0.073
	GMM	73.356	0.000	22.682	0.000	1.829	0.176	3.945	0.047
Taiwan	2SLS			32.439	0.000	3.732	0.053	8.146	0.004
	GMM	97.868	0.000	66.450	0.000	48.553	0.000	18.315	0.000
Macau	2SLS			90.365	0.000	75.760	0.000	34.277	0.000

Note: Table 2.14 reports optimal GMM and 2SLS $\chi 2$ test statistics and relative p-values. Optimal lag order is derived from the Akaike Information Criterion.

In this analysis, no country demonstrates identical impulse response patterns with China, and the null hypothesis of less strict codependence of order one is rejected for all countries. Common cyclical elements of codependence of orders two and three that capture very loose relationships are only robust for Korea, Taiwan, and Hong Kong.

2.6.3.3 Robustness Analysis

The robustness of these results is verified using an earlier canonical correlation-based version of the common features test by Tiao and Tsay (1989). Results are reported in Table 2.15. The columns of codependence of order zero and codependence of order one reveal that, again, the null hypothesis of the codependence of order zero and of order one is rejected. Regarding less strict codependence orders of two or three, more countries exhibit common cyclical elements with China. At a codependence of order two, Korea, Hong Kong, Taiwan, and Macau share common cyclical elements with China, and at a codependence of order three, Japan, Malaysia, Singapore, Korea, Hong Kong, Taiwan and Macau do as well.

To further investigate the robustness of the main results, the sample is reduced to the period before the COVID-19 crisis, as this could critically affect the analysis. As the first cases of COVID-19 were discovered in China in December 2019, the sample used for robustness checks spans 2000Q1 to 2019Q3. The results from the preliminary HEGY unit root test correspond to the previously reported results except for Indonesia, which is now also integrated at the zero frequency (see Table A2.4 in Appendix II). The results of the seasonal cointegration test (Table A2.5, Appendix II) reveal that fewer countries are cointegrated. Hong Kong, Korea and Macau no longer show cointegration relations with China on either the zero frequency or frequency π. On frequency π, however, Indonesia also shares a common stochastic seasonal trend with China.

Table 2.15 Tiao and Tsay Codependence Test – East Asian Countries and China

	Null	Codependence of order							
		0		1		2		3	
		Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
Japan	k=1	62.545	0.000	16.998	0.000	8.366	0.015	5.463	0.065
	k=2	148.666	0.000	38.057	0.000	20.802	0.002	14.158	0.028
Indonesia	k=1	59.901	0.000	17.692	0.013	12.474	0.086	2.472	0.929
	k=2	129.390	0.000	42.438	0.000	26.957	0.042	13.951	0.602
Malaysia	k=1	40.094	0.000	15.125	0.001	9.361	0.009	2.699	0.259
	k=2	145.850	0.000	34.405	0.000	22.508	0.001	16.918	0.010
Philippines	k=1	39.054	0.000	8.461	0.004	0.587	0.444	0.669	0.413
	k=2	115.744	0.000	24.246	0.000	10.889	0.028	7.663	0.105
Singapore	k=1	34.651	0.000	14.081	0.001	7.867	0.020	1.743	0.418
	k=2	159.460	0.000	36.508	0.000	22.311	0.001	18.687	0.005
Thailand	k=1	58.335	0.000	16.852	0.000	8.849	0.012	8.689	0.013
	k=2	162.857	0.000	35.823	0.000	19.875	0.003	18.239	0.006
Korea	k=1	69.469	0.000	8.953	0.011	1.140	0.566	1.990	0.370
	k=2	153.215	0.000	30.240	0.000	14.280	0.027	13.869	0.031
Hongkong	k=1	66.324	0.000	13.988	0.001	3.137	0.208	2.478	0.290
	k=2	160.980	0.000	33.578	0.000	15.117	0.020	12.724	0.048
Taiwan	k=1	46.194	0.000	6.756	0.009	0.115	0.734	0.658	0.417
	k=2	119.315	0.000	21.868	0.000	7.806	0.099	4.834	0.305
Macau	k=1	47.726	0.000	17.454	0.000	5.831	0.051	1.215	0.545
	k=2	171.419	0.000	40.458	0.000	20.035	0.003	9.665	0.139

Notes: Table 2.15 reports Tiao and Tsay (1989) test statistics and relative p-values. Optimal lag order between 1 and 7 is derived by Akaike Information.

The results of the previous two codependence tests (Korea, Taiwan, and Hong Kong show common cyclical elements with China when considering a codependence of orders two or three) are robust in the reduced sample, as is the fact that no country shares perfectly synchronized common cycles with China. Accordingly, the null hypothesis of codependence of order zero can be rejected for all countries (Table 2.16). The same is true for the somewhat less strict codependence of order one. Without the influence of the

COVID-19 crisis, however, more evidence exists for common cyclical elements at higher orders of codependence of two or three. At codependence of order three, the null hypothesis cannot be rejected for all of the countries, at least for one of the two testing procedures.

Table 2.16 Test for Codependence (before COVID-19) – East Asian Countries and China

		Codependence of order							
		0		1		2		3	
	Null	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
	GMM	75.572	0.000	25.642	0.000	9.388	0.009	3.563	0.168
Japan	2SLS			47.181	0.000	24.391	0.000	11.107	0.004
	GMM	54.766	0.000	22.289	0.004	10.276	0.246	4.588	0.801
Indonesia	2SLS			33.907	0.000	15.592	0.049	7.157	0.520
	GMM	60.954	0.000	23.713	0.000	10.590	0.005	5.049	0.080
Malaysia	2SLS			43.840	0.000	27.308	0.000	15.451	0.000
	GMM	38.382	0.000	11.200	0.001	0.239	0.624	3.850	0.050
Philippines	2SLS			18.937	0	0.486	0.486	11.863	0.001
	GMM	45.162	0.000	19.067	0.000	9.062	0.011	4.457	0.108
Singapore	2SLS			35.157	0.000	23.381	0.000	13.452	0.001
	GMM	62.806	0.000	25.280	0.000	9.934	0.007	4.358	0.113
Thailand	2SLS			46.845	0.000	23.934	0.000	11.181	0.004
	GMM	71.633	0.000	24.945	0.000	3.138	0.076	0.022	0.881
Korea	2SLS			45.146	0.000	7.434	0.006	0.063	0.802
	GMM	75.937	0.000	25.052	0.000	6.273	0.012	0.651	0.420
Hongkong	2SLS			45.538	0.000	15.406	0.000	1.889	0.169
	GMM	66.793	0.000	25.793	0.000	2.035	0.154	1.493	0.222
Taiwan	2SLS			47.550	0.000	4.736	0.029	4.150	0.042
	GMM	35.384	0.026	17.641	0.671	32.182	0.056	21.509	0.428
Macau	2SLS			19.130	0.577	10.343	0.974	6.765	0.999

Note: Table 2.16 reports optimal GMM and 2SLS $\chi 2$ test statistics and relative p-values. Optimal lag order is derived from the Akaike Information Criterion.

The Tiao and Tsay (1989) canonical correlation test (Table 2.17) confirms these results, except for Macau. For this country, at codependence of order one, the null hypothesis of no common cycle cannot be rejected.

Table 2.17 Tiao and Tsay Codependence Test (before COVID-19) – East Asian Countries and China

	Null	Codependence of order							
		0		1		2		3	
		Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
Japan	k=1	80.091	0.000	18.081	0.000	8.915	0.012	4.850	0.088
	k=2	212.395	0.000	39.875	0.000	20.493	0.002	13.125	0.041
Indonesia	k=1	74.715	0.000	21.086	0.007	13.032	0.111	9.849	0.276
	k=2	213.168	0.000	44.841	0.000	24.819	0.130	18.649	0.414
Malaysia	k=1	90.374	0.000	17.081	0.000	8.495	0.014	6.211	0.045
	k=2	224.461	0.000	41.022	0.000	21.957	0.001	17.014	0.009
Philippines	k=1	65.553	0.000	8.446	0.004	0.271	0.602	2.090	0.148
	k=2	197.102	0.000	31.102	0.000	11.731	0.019	10.209	0.037
Singapore	k=1	98.193	0.000	19.482	0.000	9.595	0.008	5.903	0.052
	k=2	230.891	0.000	44.357	0.000	24.450	0.000	18.012	0.006
Thailand	k=1	82.655	0.000	10.479	0.005	1.660	0.436	1.348	0.510
	k=2	222.227	0.000	35.361	0.000	15.915	0.014	12.009	0.062
Korea	k=1	77.206	0.000	8.111	0.004	0.862	0.353	0.106	0.745
	k=2	220.581	0.000	34.434	0.000	15.915	0.003	11.633	0.020
Hongkong	k=1	77.530	0.000	11.132	0.001	2.559	0.110	0.232	0.630
	k=2	219.094	0.000	35.219	0.000	15.620	0.004	9.905	0.042
Taiwan	k=1	65.372	0.000	6.271	0.012	0.089	0.766	1.275	0.259
	k=2	205.028	0.000	30.361	0.000	12.434	0.014	9.950	0.041
Macau	k=1	127.739	0.000	25.844	0.212	17.487	0.681	7.496	0.997
	k=2	302.880	0.000	48.317	0.303	30.775	0.934	16.845	0.999

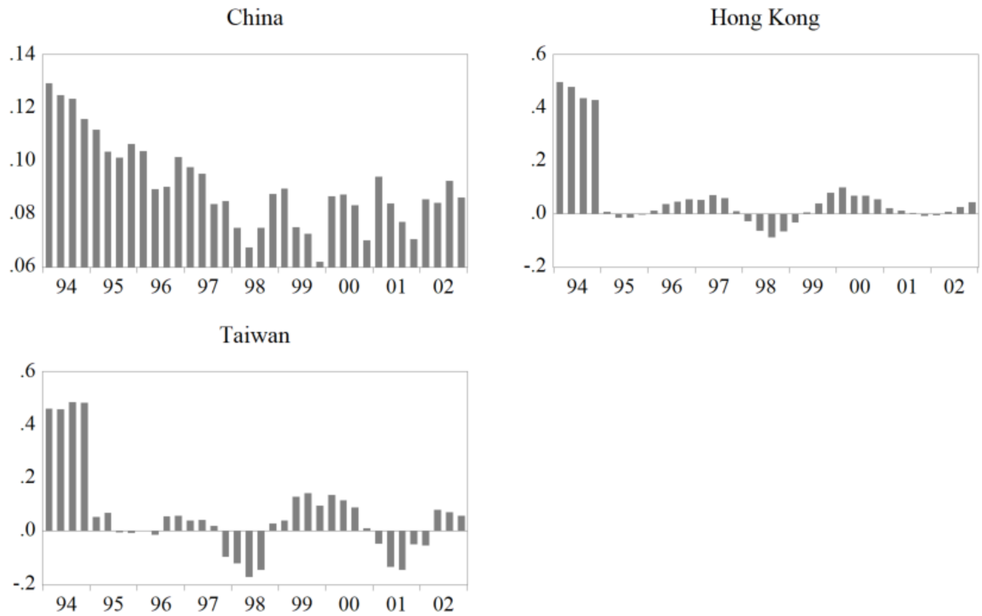
Notes: Table 2.17 reports Tiao and Tsay (1989) test statistics and relative p-values. Optimal lag order between 1 and 7 is derived by Akaike Information Criterion.

2.6.3.4 Role of Seasonal Adjustment

To further explore why these results differ from those of earlier studies by Cheung and Yuen (2005) and Sato and Zhang (2006), I also conducted the analysis for the sample used by Cheung and Yuen (2005) from 1994Q1 to 2002Q4 for Hong Kong and Taiwan (see Cheung and Yuen, 2005). Since non-seasonally adjusted data before 1978 are not available, I cannot do this accordingly for the studies of Sato and Zhang (2006). Again, I use quarterly real GDP data that is not-seasonally adjusted. The latter differs from the earlier studies.

The graphical representation of seasonal real GDP growth rates (Figure 2.13) again shows that Chinese GDP growth rates are never negative. They seem to be shifted upward compared to those of Hong Kong and Taiwan. Thus, around the Asian crisis in 1997/1998, negative growth rates are shown in the GDPs of Hong Kong and Taiwan and lower ones in China. This is followed by a rebound and again lower or negative growth rates, respectively, in 2001/02. The comparatively high growth rates for Hong Kong and Taiwan in 1994 shown in Figure 2.13 can be explained in part by changes in the exchange rate between the RMB and the Hong Kong dollar but are not exceptional, given the longer sample in Figure 2.10.

Figure 2.13 Real GDP Growth Rates – China, Hong Kong, Taiwan

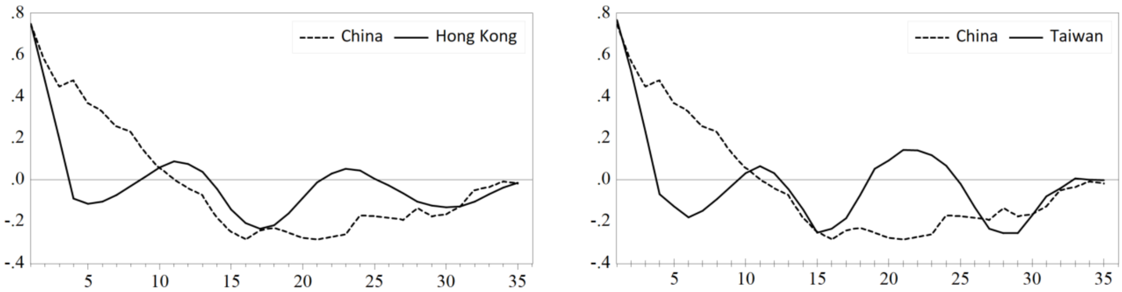


Note: Figure 2.13 depicts seasonal growth rates of real GDP (not seasonally adjusted) from 1994Q1 until 2002Q4 for China, Hong Kong, and Taiwan.

Pearson correlation coefficients between real GDP growth rates of China and Hong Kong are 0.698 and for China and Taiwan 0.690, respectively. Both coefficients are statistically significant at the 1% significance level.

In Figure 2.14, the autocorrelation functions, a standard response to an exogenous shock, are displayed for Hong Kong and Taiwan, respectively, in comparison with China. The cyclical response patterns look quite different across countries. While China displays a positive autocorrelation for the first 11 quarters, followed by a negative autocorrelation, Hong Kong and Taiwan exhibit a much shorter initial positive autocorrelation for 3 to 4 quarters, followed by a negative autocorrelation for 4 to 5 quarters and further ups and downs.

Figure 2.14 Autocorrelograms – China, Hong Kong, Taiwan



Note: Figure 2.14 shows estimated sample autocorrelation functions of real GDP growth rates (seasonal differences of l logarithmized values) over 36 quarters.

Formal tests for serial correlation common features and for codependence reveal mixed results. While the test for codependence following Cubadda (1999), reported in Table 2.18, confirms the finding of synchronous business cycles between China and Hong Kong and China and Taiwan (column: codependence of order zero), the Tiao and Tsay (1989) test, reported in Table 2.19, does not[107]. In the latter, the null hypothesis of identical impulse response patterns with China is rejected for both Hong Kong and Taiwan. At higher orders of codependence, this test also shows evidence for common cyclic elements.

[107] Results from the preliminary seasonal unit root Test and seasonal cointegration test are reported in Table A2.6 and A2.7 of Appendix II.

However, from the conceptual framework, it follows that only the strict form of identical impulse response patterns is the relevant indicator for optimal currency areas. In the rather short sample of only 36 quarters used in this section, the weakness of the common features test might also become apparent: The null hypothesis that a common feature exists could also not be rejected due to too few data points.

Table 2.18 Test for Codependence – China, Hong Kong, Taiwan

		Codependence of order							
		0		1		2		3	
	Null	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
Hongkong	GMM			0.095	0.992	0.136	0.987	0.463	0.927
	2SLS	0.642	0.887	0.104	0.991	0.075	0.995	0.417	0.937
Taiwan	GMM			0.152	0.985	0.242	0.971	0.227	0.973
	2SLS	0.612	0.894	0.124	0.989	0.131	0.988	0.283	0.963

Note: Table 2.18 reports optimal GMM and 2SLS $\chi2$ test statistics and relative p-values. Optimal lag order is derived from the Akaike Information Criterion.

Table 2.19 Tiao and Tsay Codependence Test – China, Hong Kong, Taiwan

		Codependence of order							
		0		1		2		3	
	Null	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
	k=1	16.330	0.001	3.515	0.319	2.785	0.426	7.176	0.067
Hong Kong	k=2	105.633	0.000	17.422	0.026	13.130	0.107	16.072	0.041
	k=1	15.559	0.001	2.562	0.464	4.424	0.219	1.678	0.642
Taiwan	k=2	58.041	0.000	7.518	0.482	13.172	0.106	8.623	0.375

Notes: Table 2.19 reports Tiao and Tsay (1989) test statistics and relative p-values. Optimal lag order between 1 and 7 is derived by Akaike Information Criterion.

2.7 Conclusion

The second part of this thesis examines optimal currency areas in Europe and Asia. The theory of optimal currency areas gives various criteria that can be used to examine whether countries form an optimal currency area. Frequently – and also in this study – the implicit criterion of common business cycles has been evaluated. Our contribution is that we show that not only the correlation of shocks but also the common responses to exogenous shocks are important. In the literature, the serial correlation common features test has already been used to test for common business cycles. We add to the literature by providing a theoretical underpinning for the testing procedure developed by Engle and Kozicki (1993) and others and show that this approach is indeed a model-consistent test for common dynamic impulse response patterns to shocks. In this sense, our paper may not only be relevant for the three countries currently deciding whether or not to join the EMU but more generally could serve as a guideline for currency unions or fixed exchange rate policies. In future research, for instance, the 15 countries that have recently decided to form a monetary union beyond the West African Monetary Union – possibly a full African monetary union – may be relevant applications.

In this part of the thesis, we evaluate two possible optimal currency areas with respect to this OCA criterion: the euro area and its candidate countries and a possible currency union around the Chinese RMB.

Twenty years after the first group of 12 countries started the European Monetary Union, its size has increased to 20 members. A further extension is an explicit goal of the European Union, most prominently articulated by its former president Jean-Claude Junker, who proposed the “euro for all” agenda for the coming years. On the side of the potentially acceding countries, the attitude toward joining the EMU is mixed. While Croatia just adopted the euro, two other candidate countries, Bulgaria and Romania, are pursuing a euro introduction in the foreseeable future; the others are more reluctant.

Whether EMU membership is desirable crucially depends on the welfare loss that results from the loss of a country-specific monetary policy. While a large body of literature has already explored this topic, we highlight one aspect of the debate that so far has received only little attention. It is not only the correlation of shocks between the new member state and the present currency union but also the dynamic response pattern to the shock over time that matters. While previous research has shown that the potential candidate countries appear to fit well with regard to the correlation of shocks, we show that the impulse response patterns over time are quite different for most candidate countries, i.e. evidence exists for an asymmetric response to common shocks and additional welfare losses can occur from adopting a common currency, that should be taken into account. We apply the serial correlation common feature test that has already been used by a few authors in the context of the OCA literature and came to quite similar conclusions for the group of early EMU members.

Assessing these founding members of the euro area in a sample up to 2019, I find much more evidence for common business cycles. Austria, Germany, Finland, France, Italy, and the Netherlands even share perfectly synchronized cycles with the euro area aggregate. The connection among these countries could be fostered even more by the introduction of the discussed capital markets union and banking union.

Against the backdrop of China's rise and the increasing international spread of the RMB, there are discussions about closer monetary cooperation not only in Europe but also in Asia. After the Asian financial crisis of 1997/98 and the termination of many fixed exchange rate systems of Asian currencies with the U.S. dollar, efforts toward more financial integration among East Asian countries have been made. Furthermore, China and its currency play an increasingly important role in international trade and financial markets. Based on this strengthened role of the RMB, different exchange rate regimes, even including an RMB currency bloc, have been discussed. Fixed exchange rate regimes or the adoption of a common currency may cause welfare losses, however, due to the loss of the flexible exchange rate. This is particularly true when countries react differently to shocks, and thus a common monetary policy may not be optimal for each country.

To evaluate the suitability of an RMB bloc, this study has examined whether the responses to shocks of East Asian countries are similar to those of China. This relationship has been studied previously by Sato and Zhang (2006) and Cheung and Yuen (2005). The primary difference is that this study considers the seasonality of quarterly

GDP data and does not use seasonally adjusted data. In addition, the sample analyzed in this paper is considerably longer than that of Cheung and Yuen (2005), and the data is more recent. Previous studies find more evidence for common business cycles, which I confirmed using seasonalized data. However, this result is not robust and the small sample could lead to no rejection of the null hypothesis of common cycles of the common features test. Therefore, overall, I follow my results from a longer sample which emphasize that East Asian countries do not form an optimal currency area with China from an economic perspective. The additional welfare losses from the adoption of a common currency should be considered by policymakers when forming opinions on the optimal exchange rate regime.

Appendix II

Conceptual Framework: intermediate steps

1. Loss for flexible exchange rate with persistent shocks

$L_{flex} = E[\lambda(\alpha(\pi - \pi^e) + \gamma\varepsilon_{t-1} + v_t - y^*) + \pi^2]$ |Eq. 1

FOC: $\frac{\partial L}{\partial \pi} = 2\lambda\alpha(\alpha(\pi - \pi^e) + \gamma\varepsilon_{t-1} + v_t - y*) + 2\pi \overset{!}{=} 0$ |Eq. 2

$\lambda\alpha(\alpha(\pi - \pi^e) + \gamma\varepsilon_{t-1} + v_t - y*) + \pi = 0$ | divided by 2

$\pi + v_t\alpha\lambda - \alpha\lambda y - \pi^e\alpha^2\lambda + \pi\alpha^2\lambda + \varepsilon_{t-1}\alpha\lambda\gamma = 0,$ | multiplied out

$(1 + \alpha^2\lambda)\pi = -v_t\alpha\lambda + \alpha\lambda y + \pi^e\alpha^2\lambda - \varepsilon_{t-1}\alpha\lambda\gamma$ | π-terms on LHS, Eq. 3

$(1 + \alpha^2\lambda)\pi^e = \alpha\lambda y + \pi^e\alpha^2\lambda - \varepsilon_{t-1}\alpha\lambda\gamma$ | $E_t[.]$

$\pi^e = \alpha\lambda y - \varepsilon_{t-1}\alpha\lambda\gamma = \alpha\lambda(y - \varepsilon_{t-1}\gamma)$ | solved for π^e

Lemma 1: **Inflation Bias is affected by shock persistence**

Proof: Inflation Bias w/o persistence is $\alpha\lambda y$. Difference is $-\varepsilon_{t-1}\alpha\lambda\gamma$.

(For γ = 0 → Berger et al. (2001) case.)

Solve for equilibrium π by plugging π^e into Eq. 3:

$(1 + \alpha^2\lambda)\pi = -v_t\alpha\lambda + \alpha\lambda y + (\alpha\lambda y - \varepsilon_{t-1}\alpha\lambda\gamma)\alpha^2\lambda - \varepsilon_{t-1}\alpha\lambda\gamma$

$\pi = \frac{-v_t\alpha\lambda + \alpha\lambda y + (\alpha\lambda y - \varepsilon_{t-1}\alpha\lambda\gamma)\alpha^2\lambda - \varepsilon_{t-1}\alpha\lambda\gamma}{(1+\alpha^2\lambda)}$ | Divided by $(1 + \alpha^2\lambda)$

$\pi = \frac{\alpha\lambda y + (\alpha\lambda y - \varepsilon_{t-1}\alpha\lambda\gamma)\alpha^2\lambda}{(1+\alpha^2\lambda)} - \frac{\alpha\lambda}{(1+\alpha^2\lambda)} v_t$ | v_t separate

$\pi = \alpha\lambda(y^* - \varepsilon_{t-1}\gamma) - \frac{\alpha\lambda}{(1+\alpha^2\lambda)} v_t$ | simplified

Solve for equilibrium y by plugging π^e and π into y:

$$y = \alpha(\pi - \pi^e) + \gamma\varepsilon_{t-1} + v_t$$

$$y = \alpha((\alpha\lambda(y - \varepsilon_{t-1}\gamma) - \frac{\alpha\lambda}{(1+\alpha^2\lambda)}v_t) - \alpha\lambda(y - \varepsilon_{t-1}\gamma)) + \gamma\varepsilon_{t-1} + v_t \qquad \text{| plugged in}$$

$$y = \alpha((\alpha\lambda(y - \varepsilon_{t-1}\gamma) - \frac{\alpha\lambda}{(1+\alpha^2\lambda)}v_t) - \alpha\lambda(y - \varepsilon_{t-1}\gamma)) + \gamma\varepsilon_{t-1} + v_t$$

$$y = \alpha((\alpha\lambda(y - \varepsilon\gamma) - \frac{\alpha\lambda}{(1+\alpha^2\lambda)}v) - \alpha\lambda(y - \varepsilon\gamma)) + \gamma\varepsilon + v$$

$$y = v + \gamma\varepsilon - \frac{v\alpha^2\lambda}{\lambda\alpha^2+1} \qquad \text{| simplified}$$

$$y = \gamma\varepsilon + v(1 - \frac{\alpha^2\lambda}{1+\alpha^2\lambda}) \qquad \text{| factor out v}$$

$$y = \gamma\varepsilon + v(\frac{1+\alpha^2\lambda}{1+\alpha^2\lambda} - \frac{\alpha^2\lambda}{1+\alpha^2\lambda}) \qquad \text{| extend 1 to fraction with } (1+\alpha^2\lambda) \text{ denominator}$$

$$y = \gamma\varepsilon + \frac{1}{1+\alpha^2\lambda}v$$

Plug y, π^e and π into Loss Function:

$$L_{flex} = E[\lambda(y - y^*)^2 + \pi^2]$$

$$L_{flex} = E[\lambda((\gamma\varepsilon_{t-1} + \frac{1}{1+\alpha^2\lambda}v_t) - y^*)^2 + (\alpha\lambda(y - \varepsilon_{t-1}\gamma) - \frac{\alpha\lambda}{(1+\alpha^2\lambda)}v_t)^2]$$

$$\lambda((\gamma\varepsilon + \frac{1}{1+\alpha^2\lambda}v) - y)^2 + (\alpha\lambda(y - \varepsilon\gamma) - \frac{\alpha\lambda}{(1+\alpha^2\lambda)}v)^2 \qquad \text{| expand}$$

$$= \lambda y^2 + \frac{v^2\lambda}{\alpha^4\lambda^2+2\alpha^2\lambda+1} + \lambda\gamma^2\varepsilon^2 + \alpha^2\lambda^2y^2 - \frac{2v\lambda y}{\lambda\alpha^2+1} - 2\lambda\gamma\varepsilon y + \frac{v^2\alpha^2\lambda^2}{\alpha^4\lambda^2+2\alpha^2\lambda+1} +$$
$$\alpha^2\lambda^2\gamma^2\varepsilon^2 - \frac{2v\alpha^2\lambda^2y}{\lambda\alpha^2+1} - 2\alpha^2\lambda^2\gamma\varepsilon y + \frac{2v\lambda\gamma\varepsilon}{\lambda\alpha^2+1} + \frac{2v\alpha^2\lambda^2\gamma\varepsilon}{\lambda\alpha^2+1}$$

$$L_{flex} = E[\lambda y^2 + \frac{v^2\lambda}{\alpha^4\lambda^2+2\alpha^2\lambda+1} + \lambda\gamma^2\varepsilon^2 + \alpha^2\lambda^2y^2 - \frac{2v\lambda y}{\lambda\alpha^2+1} - 2\lambda\gamma\varepsilon y + \frac{v^2\alpha^2\lambda^2}{\alpha^4\lambda^2+2\alpha^2\lambda+1} +$$
$$\alpha^2\lambda^2\gamma^2\varepsilon^2 - \frac{2v\alpha^2\lambda^2y}{\lambda\alpha^2+1} - 2\alpha^2\lambda^2\gamma\varepsilon y + \frac{2v\lambda\gamma\varepsilon}{\lambda\alpha^2+1} + \frac{2v\alpha^2\lambda^2\gamma\varepsilon}{\lambda\alpha^2+1}] \qquad \text{| take expectations}$$

$L_{flex} = \lambda y^2 + \frac{\sigma^2\lambda}{\alpha^4\lambda^2+2\alpha^2\lambda+1} + \lambda\gamma^2\varepsilon^2 + \alpha^2\lambda^2y^2 - 2\lambda\gamma\varepsilon y + \frac{\sigma^2\alpha^2\lambda^2}{\alpha^4\lambda^2+2\alpha^2\lambda+1} + \alpha^2\lambda^2\gamma^2\varepsilon^2 - 2\alpha^2\lambda^2\gamma\varepsilon y$

$L_{flex} = \frac{\lambda(\alpha^4\lambda^2\gamma^2\varepsilon^2 - 2\alpha^4\lambda^2\gamma\varepsilon y + \alpha^4\lambda^2 y^2 + 2\alpha^2\lambda\gamma^2\varepsilon^2 - 4\alpha^2\lambda\gamma\varepsilon y + 2\alpha^2\lambda y^2 + \sigma^2 + \gamma^2\varepsilon^2 - 2\gamma\varepsilon y + y^2)}{\lambda\alpha^2+1}$

Comparing with Berger, i.e. setting γ = 0 before taking expectations:

$L_{flex} = E[\lambda y^2 + \frac{v^2\lambda}{\alpha^4\lambda^2+2\alpha^2\lambda+1} + \alpha^2\lambda^2y^2 - \frac{2v\lambda y}{\lambda\alpha^2+1} + \frac{v^2\alpha^2\lambda^2}{\alpha^4\lambda^2+2\alpha^2\lambda+1} - \frac{2v\alpha^2\lambda^2 y}{\lambda\alpha^2+1}]$ | with $\gamma = 0$

$L_{flex} = \lambda y^2 + \frac{\sigma^2\lambda}{\alpha^4\lambda^2+2\alpha^2\lambda+1} + \alpha^2\lambda^2y^2 + \frac{\sigma^2\alpha^2\lambda^2}{\alpha^4\lambda^2+2\alpha^2\lambda+1}$

$$L_{flex} = \lambda y^2 + \frac{\sigma^2\lambda}{\alpha^4\lambda^2 + 2\alpha^2\lambda + 1} + \alpha^2\lambda^2y^2 + \frac{\sigma^2\alpha^2\lambda^2}{\alpha^4\lambda^2 + 2\alpha^2\lambda + 1}$$

$$L_{flex} = \frac{\lambda(\alpha^4\lambda^2y^2 + 2\alpha^2\lambda y^2 + \sigma^2 + y^2)}{\lambda\alpha^2 + 1}$$

Berger's result $L_{flex} = \frac{\sigma^2\lambda}{1+\lambda\alpha^2} + \lambda y^2 + (\alpha\lambda y)^2$

$\frac{\lambda(\alpha^4\lambda^2y^2+2\alpha^2\lambda y^2+\sigma^2+y^2)}{\lambda\alpha^2+1} - (\frac{\sigma^2\lambda}{1+\lambda\alpha^2} + \lambda y^2 + (\alpha\lambda y)^2) = 0$ (Correct!)

Difference in loss function: Persistent vs. transitory shocks

$LD = L_{flex}^{\gamma>0} - L_{flex}^{\gamma=0}$

$LD = \frac{\lambda(\alpha^4\lambda^2\gamma^2\varepsilon^2 - 2\alpha^4\lambda^2\gamma\varepsilon y + \alpha^4\lambda^2 y^2 + 2\alpha^2\lambda\gamma^2\varepsilon^2 - 4\alpha^2\lambda\gamma\varepsilon y + 2\alpha^2\lambda y^2 + \sigma^2 + \gamma^2\varepsilon^2 - 2\gamma\varepsilon y + y^2)}{\lambda\alpha^2+1} - (\frac{\sigma^2\lambda}{1+\lambda\alpha^2} + \lambda y^2 + (\alpha\lambda y)^2) = -\lambda\gamma\varepsilon(\lambda\alpha^2 + 1)(2y - \gamma\varepsilon)$

$LD = L_{flex}^{\gamma>0} - L_{flex}^{\gamma=0} = -\lambda\gamma\varepsilon(\lambda\alpha^2 + 1)(2y - \gamma\varepsilon)$

Exchange Rate decision before period 1; taking unconditional expected values:

$$L_{flex} = \lambda y^2 + \frac{\sigma^2\lambda}{\alpha^4\lambda^2 + 2\alpha^2\lambda + 1} + \lambda\gamma^2\varepsilon^2 + \alpha^2\lambda^2y^2 - 2\lambda\gamma\varepsilon y + \frac{\sigma^2\alpha^2\lambda^2}{\alpha^4\lambda^2 + 2\alpha^2\lambda + 1} + \alpha^2\lambda^2\gamma^2\varepsilon^2 - 2\alpha^2\lambda^2\gamma\varepsilon y$$

becomes:

$$L_{flex} = \lambda y^2 + \frac{\sigma^2\lambda}{\alpha^4\lambda^2 + 2\alpha^2\lambda + 1} + \alpha^2\lambda^2 y^2 + \frac{\sigma^2\alpha^2\lambda^2}{\alpha^4\lambda^2 + 2\alpha^2\lambda + 1}$$
$$= \frac{\lambda(\alpha^4\lambda^2 y^2 + 2\alpha^2\lambda y^2 + \sigma^2 + y^2)}{\lambda\alpha^2 + 1}$$

Compare with transitory-shock case:

$$LD = L_{flex}^{\gamma>0} - L_{flex}^{\gamma=0}$$

$$LD = \frac{\lambda(\alpha^4\lambda^2y^2+2\alpha^2\lambda y^2+\sigma^2+y^2)}{\lambda\alpha^2+1} - (\frac{\sigma^2\lambda}{1+\lambda\alpha^2} + \lambda y^2 + (\alpha\lambda y)^2) = 0$$

Lemma 2. *The shock persistence does not affect expected losses in a flexible exchange rate case.* i.e. $E[L_{flex}^{\gamma\neq 0}] - E[L_{flex}^{\gamma=0}] = 0$.

Difference in loss functions for fixed exchange rate with persistent Shocks

$$\varepsilon_t = \gamma_1\varepsilon_{t-1} + v_t; \theta_t = \delta_1\theta_{t-1} + u_t$$

$$L^{fix} = E[\lambda(\alpha u_t + \gamma_1\varepsilon_{t-1} + v_t - y^*)^2 + (\pi^* + \delta_1\theta_{t-1} + u_t)^2]$$

Set u=v and expand:

$$L^{fix} = E[{\theta_{t-1}}^2\delta_1^2 + 2\pi v_t + v_t^2\lambda + \lambda y^2 + \pi^2 + v_t^2 + 2v_t^2\alpha\lambda + v_t^2\alpha^2\lambda + \lambda\gamma_1^2{\varepsilon_{t-1}}^2$$
$$+ 2\pi\theta_{t-1}\delta_1 + 2v_t\theta_{t-1}\delta_1 - 2v_t\lambda y + 2v_t\lambda\gamma_1\varepsilon_{t-1} - 2v_t\alpha\lambda y$$
$$- 2\lambda\gamma_1\varepsilon_{t-1}y + 2v_t\alpha\lambda\gamma_1\varepsilon_{t-1}]$$

Take unconditional expectation:

$$L^{fix} = var(\theta_t)\delta_1^2 + \sigma_v^2\lambda + \lambda y^2 + \pi^2 + \sigma_v^2 + 2\sigma_v^2\alpha\lambda + \sigma_v^2\alpha^2\lambda + \lambda\gamma_1^2 var(\varepsilon_t)$$

Because:

$$E(v_t^2) = \sigma_v^2$$

$E(v_t) = 0$

$E(\theta_{t-1}) = 0$

$E(\theta_{t-1}^2) = var(\theta_t)$

$E(\varepsilon_{t-1}) = 0$

$E(\varepsilon_{t-1}^2) = var(\varepsilon_t)$

Compare loss function with case $\boldsymbol{\delta = \gamma}$

$$d = L_{\delta \neq \gamma}^{fix} - L_{\delta = \gamma}^{fix}$$

$$= var(\theta_t)\delta_1^2 + \sigma_v^2\lambda + \lambda y^2 + \pi^2 + \sigma_v^2 + 2\sigma_v^2\alpha\lambda + \sigma_v^2\alpha^2\lambda$$
$$+ \lambda\gamma_1^2 var(\varepsilon_t)$$
$$- \left(var(\theta_t)\gamma_1^2 + \sigma_v^2\lambda + \lambda y^2 + \pi^2 + \sigma_v^2 + 2\sigma_v^2\alpha\lambda + \sigma_v^2\alpha^2\lambda\right.$$
$$\left. + \lambda\gamma_1^2 var(\varepsilon_t)\right) = var(\theta_t)\delta_1^2 - var(\theta_t)\gamma_1^2$$

$d = var(\theta_t)(\delta_1^2 - \gamma_1^2)$, where $var(\theta_t) = \frac{\sigma_v^2}{(1-{\delta_1}^2)}$

Zero iff $\delta = \gamma$.

d is positive for $\gamma < \delta$

d is negative for $\gamma > \delta$

Effect increases in distance between δ and γ

Effect goes to infinity for $\lim\limits_{\delta_1 \to 1}$.

Proposition 3. *When joining a monetary union, there is an additional welfare gain/loss from asymmetric persistence.*

Proof. $E\left[L_{fix}^{\delta\neq\gamma}\right] - \mathrm{E}\left[L_{fix}^{\delta=\gamma}\right] = var(\theta_t)(\delta^2 - \gamma^2)$, *with* $var(\theta_t) = \frac{\sigma_v^2}{(1-\delta^2)}$. *The expression is zero if, and only if,* $\delta = \gamma$.

Corollary 4 *The only symmetric equilibrium where two countries find it optimal to form a monetary union is the when* $\delta = \gamma$.

Table A2.1 HEGY Unit Root Test – Eurozone Members

	Frequency			
Country	0	π	π/2	All seasonal frequencies
Austria	-3.768**	-3.773***	23.146***	20.703***
EA12-Austria	-3.111*	-3.403**	18.100***	15.547***
Belgium	-3.174*	-4.156***	19.156***	17.780***
EA12-Belgium	-3.142*	-3.370**	18.283***	15.624***
Germany	-3.582**	-3.102**	18.932***	15.562***
EA12-Germany	-2.771	-3.558***	16.863***	15.022***
Spain	-2.620	-3.671***	17.900***	15.903***
EA12-Spain	-3.324*	-3.357**	18.423***	15.706***
Finland	-2.954	-4.078***	18.788***	17.243***
EA12-Finland	-3.166*	-3.410**	18.390***	15.777***
France	-3.535**	-3.718***	14.879***	14.167***
EA12-France	-2.032	-3.314**	19.565***	16.305***
Greece	-2.021	-2.380	10.957***	8.900***
EA12-Greece	-3.280*	-3.402**	18.634***	15.960***
Ireland	-0.574	-2.067	10.534***	8.316***
EA12-Ireland	-3.256*	-3.548***	18.501***	16.142***
Italy	-3.241*	-2.989**	14.023***	12.087***
EA12-Italy	-3.139*	-3.522***	19.435***	16.719***
Luxembourg	-2.476	-3.360**	10.226***	10.410***
EA12-Luxembourg	-3.160*	-3.418***	18.431***	15.818***
Netherlands	-2.718	-3.777***	13.600***	13.351***
EA12-Netherlands	-3.190*	-3.312**	17.815***	15.200***
Portugal	-2.142	-4.357***	20.064***	19.234***
EA12-Portugal	-3.171*	-3.400**	18.369***	15.733***

Note: Table A2.1 shows results from the HEGY seasonal unit root test (see Hylleberg et al., 1990) for log-levels of seasonally unadjusted GDP. Regressors include, intercept, trend, and seasonal dummies. Optimal lag order between 1 and 7 is derived automatically from the Akaike Information Criterion.

Table A2.2 Seasonal Cointegration Test – Eurozone Members

		0		π	
Country	Lags	r = 0	r ≤ 1	r = 0	r ≤ 1
Austria	6	7.676	0.048		
Belgium	5	6.646	0.737		
Germany	7	13.297**	0.019	10.382**	0.057
Spain	5	10.991*	0.220		
Finland	6	9.806	1.391		
France	6	6.068	0.473		
Greece	7	9.047	0.797		
Ireland	6	9.872	0.049		
Italy	6	2.717	0.101		
Luxembourg	5	5.700	2.052		
Netherlands	6	20.762***	0.163	16.235***	0.059
Portugal	7	9.735	3.897		

Notes: Table A2.2 shows results from a bivariate (against EA12) seasonal cointegration test for log levels of seasonally unadjusted real GDP. Trace Statistics. *, **, *** indicates the rejection of the null based on linearly interpolated critical values of Lee and Siklos (1995). Optimal lag order between 1 and 7 is derived by Akaike Information Criterion of the bivariate VAR incl. deterministic trends and seasonal dummies.

Table A2.3 Tiao and Tsay Codependence Test – Eurozone Members

			Codependence of order							
			0		1		2		3	
Country	Lags	Null	Stat	Prob	Stat	Prob	Stat	Prob	Stat	Prob
Austria	6	k=1	53.014	0.000	22.083	0.024	12.365	0.337	5.541	0.902
	6	k=2	193.081	0.000	45.902	0.005	28.016	0.259	18.078	0.799
Belgium	5	k=1	74.166	0.000	25.559	0.003	13.010	0.162	4.141	0.902
	5	k=2	215766	0.000	51.280	0.000	34.590	0.022	13.722	0.844
Germany	7	k=1	102.316	0.000	24.682	0.038	15.943	0.317	9.528	0.796
	7	k=2	293.022	0.000	51.910	0.008	31.319	0.400	19.991	0.917
Spain	5	k=1	103.427	0.000	21.135	0.012	12.387	0.192	8.137	0.520
	5	k=2	298.097	0.000	47.710	0.000	26.576	0.148	17.390	0.628
Finland	6	k=1	51.162	0.000	24.407	0.011	14.660	0.199	5.246	0.919
	6	k=2	182.453	0.000	47.312	0.003	31.203	0.148	19.867	0.704
France	6	k=1	68.390	0.000	15.357	0.167	9.703	0.557	4.213	0.963
	6	k=2	200.012	0.000	39.982	0.021	23.075	0.515	11.154	0.988
Greece	7	k=1	132.673	0.000	23.944	0.032	13.514	0.409	7.027	0.901
	7	k=2	278.212	0.000	52.841	0.003	30.674	0.332	18.338	0.917
Ireland	6	k=1	57.366	0.000	15.006	0.241	18.891	0.091	5.117	0.954
	6	k=2	191.025	0.000	38.555	0.054	31.502	0.210	12.524	0.988
Italy	6	k=1	56.225	0.000	15.164	0.175	7.367	0.769	3.485	0.983
	6	k=2	186.982	0.000	40.419	0.019	21.968	0.581	8.278	0.999
Luxembourg	5	k=1	51.304	0.000	16.975	0.049	10.630	0.302	1.999	0.991
	5	k=2	186.066	0.000	43.383	0.002	29.544	0.078	21.253	0.382
Netherlands	6	k=1	73.362	0.000	21.659	0.042	12.151	0.434	6.636	0.881
	6	k=2	232.532	0.000	48.972	0.004	29.224	0.301	20.794	0.753
Portugal	7	k=1	98.283	0.000	25.232	0.022	13.096	0.440	6.140	0.941
	7	k=2	243.793	0.000	51.152	0.005	26.520	0.545	13.645	0.990

Notes: Table A2.3 reports Tiao and Tsay (1989) test statistics and relative p-values. Optimal lag order between 1 and 7 is derived by Akaike Information Criterion of the bivariate VAR incl. deterministic trends and seasonal dummies.

Table A2.4 HEGY Unit Root Test (Before COVID-19) – Asian Countries and China

	Frequency			
Country	0	PI	PI/2	All seasonal frequencies
Japan	-2.906	-3.856***	13.143***	13.215***
Indonesia	-3.553	-5.694***	12.663***	24.663***
Malaysia	-2.237	-4.793***	24.686***	25.897***
Philippines	-3.994***	-3.234**	12.887***	11.917***
Singapore	-2.296	-4.330***	16.073***	17.776***
Thailand	-2.837	-3.388**	9.488***	10-651***
Korea	-2.264	-5.963***	22.235***	29.325***
Hong Kong	-2.085	-4.306***	13.569***	15..184***
Taiwan	-2.476	-4.589***	17.055***	19.344***
Macau	-1.292	-3.961***	7.029***	10.199***
China	-0.257	-3.312**	10.235***	11.135***

Note: Table A2.4 shows results from the HEGY seasonal unit root test (see Hylleberg et al., 1990) for log-levels of seasonally unadjusted GDP. Regressors include, intercept, trend, and seasonal dummies. Optimal lag order between 1 and 7 is derived automatically from the Akaike Information Criterion.

Table A2.5 Seasonal Cointegration Test (Before COVID-19) – East Asian Countries and China

	0		π	
	r = 0	r ≤ 1	r = 0	r ≤ 1
Japan	17.396***	55.857***	31.374***	8.245*
Indonesia	21.496***	8.217	35.876***	3.983
Malaysia	16.897**	5.737	35.857***	11.502**
Philippines	21.395***	8.442	-	-
Singapore	25.063***	5.967	31.462***	10.348**
Thailand	14.299**	6.787	27.021***	8.470*
Korea	11.681*	4.88	-	-
Hong Kong	9.729	2.256	-	-
Taiwan	10.518	2.466	-	-
Macau	9.759	4.347	-	-

Notes: Table A2.5 shows results from a bivariate (against EA12) seasonal cointegration test for log levels of seasonally unadjusted real GDP. Trace Statistics. *, **, *** indicates the rejection of the null based on linearly interpolated critical values of Lee and Siklos (1995). Optimal lag order between 1 and 7 is derived by Akaike Information Criterion.

Table A2.6 HEGY Unit Root Test – China, Hong Kong, Taiwan

	Frequency			
Country	0	π	π/2	All seasonal frequencies
China	-2.885	0.452	3.087	2.226
Hong Kong	-2.827	-3.297**	3.189	5.472*
Taiwan	-2.313	-2.687*	11.524***	8.871**

Note: Table 2.6 shows results from the HEGY seasonal unit root test (see Hylleberg et al., 1990) for log-levels of seasonally unadjusted GDP. Regressors include, intercept, trend, and seasonal dummies. Optimal lag order between 1 and 7 is derived automatically from the Akaike Information Criterion.

Table A2.7 Seasonal Cointegration Test – China, Hong Kong, Taiwan

	0		π		$\pi/2$	
	r = 0	r ≤ 1	r = 0	r ≤ 1	r = 0	r ≤ 1
Hong Kong	19.344	0.063	14.433	1.955	5.163	0.747
Taiwan	9.075	1.559			-	-

Notes: Table A2.7 shows results from a bivariate (against EA12) seasonal cointegration test for log levels of seasonally unadjusted real GDP. Trace Statistics. *, **, *** indicates the rejection of the null based on linearly interpolated critical values of Lee and Siklos (1995). Optimal lag order between 1 and 7 is derived by Akaike Information Criterion.

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