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Three Essays in International Macroeconomics

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THREE ESSAYS IN INTERNATIONAL MACROECONOMICS

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Business and Economics at the University of Kentucky

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ABSTRACT OF DISSERTATION

THREE ESSAYS IN INTERNATIONAL MACROECONOMICS

This dissertation spans topics related to global trade, oil prices, optimum currency areas, the eurozone, monetary independence, capital controls and the international monetary policy trilemma. It consists of four chapters and three essays. Chapter one provides a brief summary of all three essays. Chapter two investigates the impact of oil prices on global trade. It is concluded that when oil prices increase, countries start trading relatively more with their neighbors. As an application this chapter provides a new estimate of the eurozone effect on trade. Chapter three continues to study the eurozone and asks whether it is an optimum currency area using the member countries' desired monetary policies. It is concluded that Greece, Spain, and Ireland have desired policies that are the least compatible with the common euro policy and are therefore the least likely to have formed an optimum currency area with the euro. Chapter four provides a new methodology in testing the international trilemma hypothesis. It is concluded that the trilemma holds in the context of the Asian countries.

KEYWORDS: Capital controls, the Taylor rule, optimum currency area, monetary independence, gravity model, oil price

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1 Introduction

This dissertation focuses on international macroeconomics with topics related to global trade, currency unions, monetary independence, and capital controls.

The first essay studies the impact of oil prices on global trade. It concludes that oil prices have a distributional effect on trade. In particular when oil prices increase, trade becomes relatively more localized as countries trade more with their neighbors. On the other hand, when they decrease trade becomes relatively more dispersed as countries start trading more with distant partners. As an application of the hypothesis, this essay provides a more realistic estimate of the eurozone effect on trade (trade within the euro members). The creation of the eurozone corresponded with a major oil price increase since 1999. As the euro countries tend to be closer together, the oil price increase can explain part of why trade increased more within the eurozone compared to the country-pairs outside the eurozone they are normally compared to. When the oil price increase since 1999 is taken into account the eurozone effect on trade is reduced by as much as a third.

In the second essay I continue to study the eurozone and ask whether it is an optimum currency area by assessing the cost of joining. A large cost of joining arises from the fact that countries have to give up their own monetary autonomy in order to share a common currency, and the common monetary policies may not be fully appropriate for all members. In this essay I approximate the Taylor-rule based interest rate as the desired policy of each member. Countries that have own desired policies similar to those of the ECB are said to form an optimum currency area with the euro; further as their desired policies are being realized it is as if they have retained their monetary independence. On the other hand, countries that have desired policies different from the ECB policies are said to have paid a large cost for joining as their desired policies are not being realized; in this case the countries do not form an optimum currency area and are considered monetarily dependent. The results show this to be the case for Spain, Ireland, and Greece.

The third essay applies the above monetary independence methodology to countries outside currency unions and provides a new way to measure the international trilemma hypothesis - the tradeoff between exchange rate stability, monetary independence, and capital controls. Using the traditional covered interest rate parity condition we are able to construct measures of the trilemma components and thus confirm the trilemma's existence in the context of the Asian countries. In particular we find that countries with greater exchange rate flexibility and capital controls have more monetary independence. We also augment the traditional monetary independence regression to include each country's desired interest rate. The results show that the most monetary dependent countries become significantly more independent after the desired interest rate is included.

2 The Impact of Oil Prices and Trade with an Application to the Euro's Trade Effect

2.1 Introduction

In macroeconomics oil price changes, being motivated by the 1970's stagflation period, have generally been associated with the role they play in the overall economy. The literature treats increases in the oil price as contemporaneously exogenous shocks and then uses VARs to study the economy's response to these shocks.[1] Unlike this mainstream literature, the aim of this study is to explore the way oil prices alter the patterns of global trade. This research considers oil prices from the perspective of the trade literature where they can be seen as influencing trade costs.[2] In theory, changes in trade costs will only alter the allocation or the distribution of trade, and therefore the way oil prices influence trade through their short run impact on the economy is beyond the scope of this paper.[3] Nonetheless, any changes through the economy should not really impact the trade distribution results presented here.

In present times, crude oil is the most significant driving force behind world transportation, supplying 93 percent of its energy needs (IEA, 2012). Since the last decade, world oil prices have dramatically increased from an average of twenty dollars a barrel in 1999 (in 2005 dollars) to reaching over ninety dollars a barrel in 2008. Despite these drastic changes, surprisingly little to no notable research has formally investigated crude oil's impact on global trade.[4] It is reasonable to assume that oil prices are related to trade costs in particular shipping, and thus changes in shipping will likely drive changes in trade. In a regression, Hummels (2007) confirms that fuel costs play an important role in the determination of ad valorem freight costs. Then, the literature has shown that shipping costs significantly influence trade (Geraci and Prewo,1977, Harrigan,1993, Hummels,1999, and Hummels, Lugovskyy, and Skiba,2009). Further, if

[1] Some notable papers include Hamilton (1983, 1996), Rotemberg and Woodford(1996), Blanchard and Gali(2007), and Kilian(2009).
[2] For an extensive review of trade costs and their influence on trade see Anderson and van Wincoop(2004).
[3] For example, Backus and Crucini(2000) and Kilian, Rebucci, and Spatafora(2009) study the way oil price shocks effect the terms of trade and/or the trade balance.
[4] Brun et al. (2005) incorporate oil prices as a purely time variant variable in the gravity model.

shipping costs are assumed to be (partly) proxied by distance, it is well known that they play a central role in trade behavior.

Trade might be impacted in different ways. The gravity model of trade can be used for theoretical predictions.[5] One possibility is that a change in the oil price leads to the same percent change in shipping/trade costs for all countries. However if this is the case then theoretically there should be no change in trade.[6] Alternatively, oil prices might have a different impact on trade costs (and therefore trade) depending on distance. This paper argues that as oil prices rise, countries will tend to increase trade with their neighbors relative to countries further away. This way trade becomes more localized relative to before. On the other hand, when oil prices fall, distance becomes less of a factor and trade becomes more dispersed. This is a reasonable hypothesis; as shipping costs are generally a more significant portion of a product's price for longer distances, changes in shipping will likely have a greater effect on the product's final delivered price for the longer distance. The gravity model of trade is then able to explain how these changes in shipping produce inverse changes in trade depending on the distance.

This distributional oil price effect is formally tested here by introducing an oil price-distance interaction variable in a panel fixed effects gravity regression using all world countries. This type of regression controls for all time invariant country-pair specific unobservables, and therefore exploits the within country-pair variation of trade over time. Further, year dummies are also included to control for overall year specific world trade effects. The interaction variable then does not capture absolute trade changes but just relative trade changes due to the different country-pair distances. In

[5] The gravity model of trade is an important empirical tool in the trade literature. The model states that the trade value between two regions largely depends negatively on their distance and positively on their GDPs. Here, trade is analogous to gravity in that the gravitational pull between two bodies depends on their mass and distance. For early works see Tinbergen (1962), Poyhonen (1963), and Linnemann (1966). For a review of more recent works see Karlaftis et al. (2010).

[6] The general equilibrium version of the gravity model by Anderson and van Wincoop (2003) predicts that the gravity equation is homogenous of degree zero in trade costs. In other words, if oil prices change trade costs by the same percentage for all countries (including internally), then there will be no change in the value traded (assuming GDPs stay constant).

other words, the term captures the magnitude of a change in world trade dispersion due to a change in the oil price. In all the specifications, the interaction effect turns out to be significant and with the correct sign, implying that global trade becomes more localized when oil prices increase.

This oil price interaction also makes the panel gravity equation more complete by accounting for time varying shipping costs. This might have many applications, one of which is the eurozone effect on trade.[7] This effect measures the percentage increase in trade within the countries of the eurozone that is due to the sharing of the common currency. It is worth to reconsider this effect as the eurozone has recently been in turmoil and its existence has come into question. The methodology of estimation is generally done by including a eurozone dummy variable in a panel fixed effects gravity regression.[8] The coefficient in-front of the dummy then acts like a difference-in-differences estimate as it compares how trade changed within the eurozone members relative to other industrialized country-pairs before and after 1999. Recent estimates and the estimates from this paper (without accounting for oil prices) point to a eurozone effect of roughly 10%. However, as can be seen in Figure 2.1, oil prices have dramatically increased since 1999. As the eurozone members tend to be close together, the oil price increase can explain part of why trade increased more within the eurozone relative to the industrialized countries outside the eurozone they are normally compared to. Based on the regression specifications, it is concluded that the eurozone effect falls to less than 7% once oil prices are taken into account and to less than 5% after the general equilibrium effects are taken into account.[9]

The rest of this paper is organized as follows: Section 2.2 discusses theory and gives evidence for the link between oil prices, shipping costs, and trade. Section 2.3

[7] This effect falls under the umbrella of estimations used to estimate the currency union effect of trade (Rose, 2000, and Glick and Rose, 2002, Rose and van Wincoop, 2001).
[8] This methodology has been commonly used in currency union estimations, and in particular the eurozone (Micco, Stein, and Ordonez, 2003, Frankel, 2010, and Baldwin and Taglioni, 2006).
[9] The general equilibrium effects take into account changes in the multilateral resistance terms, and are therefore another contribution of this paper.

formally tests the above hypothesis by incorporating an oil price-distance interaction variable in a gravity equation. Section 2.4 provides the specifications and results from the traditional gravity model. Section 2.5 applies the interaction variable to the more modern Anderson and van Wincoop (2003) general equilibrium (GE) version of the gravity model and reports the GE estimation results and impact of oil prices. Section 2.6 includes the interaction variable in estimating the eurozone effect on trade. Lastly, section 2.7 concludes. The figures, tables and appendix are at the end.

2.2 Oil Prices and Shipping Costs

This section first introduces theory and then provides real world evidence as to how oil prices influence shipping costs and therefore trade.

2.2.1 The Link between Oil Prices, Shipping, and Trade

Hummels (2007 p.134) states that consumers are sensitive to the final delivered price of a product and not just its shipping cost or production price alone.[10] For example, consider two similar products with a production price of 10 dollars each, and that one type has to travel a short distance and the other a long distance to reach their destination with shipping costs 1, and 2 dollars per unit respectively. Now suppose oil prices increase and the shipping costs double for both distances. The ratio of the delivered prices before the oil price increase was $12 to $11, but after it becomes $14 to $12. In other words, the further product became more expensive relative to the closer product. Intuitively, this is because shipping costs are a smaller fraction of the production price for the closer destination, so any proportional changes to the shipping costs will have a smaller impact on the delivered price for the closer destination. This change in the relative delivered prices will thus drive change in the total value of the product traded. Therefore, it is the changes in the *ad-valorem*[11] shipping costs that

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[10] Suppose a product is produced at an origin and travels to a destination. Then the delivered price of a product is defined as the product's price at the origin plus the shipping cost to the destination.

[11] An *ad valorem* shipping cost is the shipping cost of a product expressed as a fraction of the production price of a product. In this case $ad\ valorem\ \text{shipping cost}\ = \frac{\text{delivered price of a product}}{\text{production price of a product}}$ where $\text{delivered price} = actual\ \text{shipping cost}\ +\ \text{production price}$. For example if a product is $10 at the

really matter. The theoretical gravity model by Anderson and van Wincoop (2003), denoted hereafter as AvW, likewise confirms this (see Appendix C for a summary of the model). In AvW the trade costs (including shipping) are clearly *ad valorem*. As footnote 6 implies, in order for changes in trade to occur, there has to be changes in the relative trade costs. In the example, even though the *actual* shipping costs doubled for both distances, the *ad-valorem* shipping costs (and delivered prices) increased by a greater percentage for the longer distance. According to the AvW gravity model (with $\sigma > 1$), this increase will drive a relative decrease in the total value exported to the longer distance.

In conclusion, if countries further apart have a higher *ad valorem* shipping cost to begin with[12], and an oil price hike increases the *actual* shipping cost by the same percentage for all distances, then the *ad valorem* shipping cost (and delivered price) will increase by a larger fraction for countries further apart.[13] In this case, consumers will find that products further away have become relatively more expensive and will substitute towards the cheaper products closer to or at the home country. The opposite will be true when oil prices decrease.

The above argument was made considering that the *actual* shipping cost increased by the same percentage for both short and long distances. However, in the real world the *actual* shipping cost might realistically increase by a larger percentage for the longer distance; however, this will not change the basic result. For example, consider the total shipping cost as the sum of a fixed cost and a variable cost. For simplicity, assume that the fixed cost is for the loading and unloading of cargo, and is independent of the distance traveled, while the variable cost is the distance traveled

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production location and the shipping to a particular destination costs $2, then the ad valorem shipping cost is 1.2.

[12] This is shown in Figure 2 (discussed in the next subsection) for countries that are more than 4000 miles apart to countries that are less than 4000 miles apart, and is also consistent with empirical results. In the AvW gravity model distance can be seen as a proxy for *ad valorem* shipping costs. In the real world its estimated trade cost impact is usually always significantly negative.

[13] This can be seen from the formula: $ad\ valorem \text{ shipping cost} = \frac{actual \text{ shipping cost}}{\text{production price}} + 1$. As the AvW model is a general equilibrium model, the production prices will also change slightly because of changing relative ad valorem shipping costs, but this will not change the overall results.

times the oil price (a proxy for the fuel cost). Then, for a given transported product, a doubling of the oil price will double the variable cost, and will thus increase the total shipping cost by a larger percentage for the longer distance. The logic here is that the variable cost is a much larger fraction of the total shipping cost for the longer distance to begin with; therefore, any changes to the variable cost will impact the longer distance by more.

2.2.2 Real World Evidence

According to Annex A in the IEA (2012) – World Energy Outlook, as of 2010, 93% of the world's energy needs in transportation are met through petroleum. Petroleum based products mainly include petrol (gasoline) for cars and small boats; diesel for trucks, trains, and ships; and kerosene for aircraft (Gilbert and Perl, 2013, p.120). All these products are made from oil distillation, and so they are highly responsive to the price of oil.[14]

Although, oil constitutes a large portion of transportation energy needs, it is important to analyze whether changes in these energy costs play a significant role in changing ad valorem shipping costs. A way to obtain ad valorem shipping costs is to compare the ratios of CIF (cost, insurance and freight) imports to FOB (free on board) exports. When products are exported internationally, their value is recorded without the shipping cost and insurance. When they are imported, their value is recorded with the shipping cost and insurance. The IMF Direction of Trade Statistics has annual data on CIF imports, and corresponding FOB exports for each exporter-importer pair. Then, for all world exporter-importer and year (1952-2012), the CIF to FOB ratio is constructed as a measure of the ad valorem shipping cost for the particular pair in the given year.[15] This paper follows Hummels and Lugovskyy (2006) in restricting the data to the reasonable

[14] See Emmons and Neely (2007), and Borenstein et al.(1997) for the behavior of petrol.

[15] Inferring ad valorem shipping costs from this ratio has received criticisms (Hummels and Lugovskyy, 2006). However this paper does not use the shipping costs for any formal results but just for a visual big picture. To my knowledge using the ratios is the standard way of obtaining a long time series on ad valorem shipping costs for all world country-pairs.

values of the ratio, between 1 and 2, implying an ad valorem shipping cost of 0% to 100% of the shipment value.

After the unreasonable observations are removed, for each year, the sum of all world imports divided by the sum of all world exports is then used to construct an overall ratio for the world ad valorem shipping cost. The middle "overall" curve in Figure 2.2 shows how this ratio has changed over the years. There are clear ups and downs, with some of the trend corresponding to the log of the real Brent Crude oil price (black curve). However, theoretically, the overall level of ad valorem costs is not going to change the distribution of trade. It is actually important to compare how the ad valorem shipping cost has changed for the different distances. The distance is taken to be the great circle distance calculated from the geographic center of the countries using coordinates from the CIA World Factbook. The average distance in the sample is around 4000 miles, so the "dist>4k" and "dist<4k" show the shipping costs only for pairs more than 4000 miles apart, and less than 4000 miles apart respectively. In other words, the "dist>4k" curve represents $\frac{\sum imports\ for\ dist>4k}{\sum exports\ for\ dist>4k}$ for each year. It is clear from the graph that, in general, country pairs more than 4000 miles apart have higher ad valorem shipping costs than countries less than 4000 miles apart. The overall trend for all curves does appear to be similar. It is a bit unusual that the trend increases in the 1990s and then decreases in the 2000s – the opposite in the movement of the oil price.

The overall trend behavior of the ad valorem shipping costs is of no interest in this paper, as this by itself will not alter trade.[16] What is of interest is how expensive the longer distance is relative to the shorter distance, and so it is ultimately the difference between the two outer curves that will determine the behavior of trade. The graph in Figure 2.2 does show evidence that these shipping costs were of similar magnitude when oil prices were low (in the 90s), but became vastly different when they were high (in the 70s and 2000s), with the dist>4k becoming relatively more expensive than the

[16] Theory predicts that there will be no change in trade allocation if ad-valorem trade costs changed by the same percentage everywhere (including internally) – see footnote 6.

dist<4k. To compare the shipping cost of the longer distance to the shorter distance, the ratio of the two ad valorem costs $\frac{\sum imports\ for\ dist>4k}{\sum exports\ for\ dist>4k} / \frac{\sum imports\ for\ dist<4k}{\sum exports\ for\ dist<4k}$ is used. Figure 2.3, the blue curve, shows how this ratio changes throughout the years. As can be seen, there is a more clear fit that corresponds with oil prices. The smallest difference appears to be in 2002, and then a large jump until around 2005 where the shipping cost difference does appear to remain high afterwards. A more extreme case is shown in the darker "dist>9k/dist<2k" curve, which compares shipping for a distance of greater than 9000 miles to shipping for a distance of less than 2000 miles. It is clearly seen that this curve is even more correlated with the oil price. Changes in relative shipping costs do appear to be volatile before the 1970s, however, world trade was low then (and even lower for distances > 9000 miles), and perhaps the spikes are the pricing decisions of just a few large shipping firms or for just a few large shipments. The oil price was also highly regulated at this time and non-price rationing of oil was commonly used (Hamilton, 2011). Furthermore, there are different indexes used to measure oil price. In Hamilton (1983), the producer price index of crude oil shows several mild shocks to the oil price in the 50s and 60s. The first is from the removal of the oil price controls in 1953. The second is from the Suez Canal crisis that blocked shipments through the canal in 1956-57. As supply increases after opening, there is an oil price decrease in 1959. There are also a couple of mild increases in oil price in the late 60s.

As seen from Figure 2.3, when oil prices rise, ad valorem shipping costs became more expensive for the longer distance relative to the shorter distance, and vice versa when oil prices fall. Then, in accordance with the gravity model, the relative increase in the costs for the longer distance will drive trade to become more localized, while the relative decrease will drive trade to become more dispersed. According to Figure 2.3, the magnitudes might not seem large. For example, the difference between the over 9000 mile and the below 2000 mile ad valorem cost was around 5% in 1999, but rose to 15% by 2008. Although this is a relative difference of roughly 10%, according to the AvW gravity model it has a substantial impact on trade because in the model the goods are generally seen to be highly substitutable. For example, if σ is assumed to be around 5 (as in AvW), this implies a multiplying factor of 4 (elasticity of trade costs is $1-\sigma$) for the percent decrease in trade. It is difficult to obtain actual numbers for the decrease because this will depend on the delivered prices of all potential partners; see equation (4c) in Appendix C, but in general this can be interpreted as around a 40% drop in trade for the >9000k distance relative to the <2000k distance when oil prices increase from $20 in 1999 to $90 in 2008.

2.3 The Interaction Term and Estimation

The previous section provided an argument and evidence for how oil prices would change trade. The goal of this section is to introduce the methodology in actually testing the hypothesis. The basic idea is that an oil price-distance interaction term will be incorporated in a gravity regression.

2.3.1 The Interaction Term

The purpose of the interaction term is to show that the percent change in trade, due to an oil price change, also depends on the distance. Ultimately, this term is to capture the effect that trade becomes more localized when oil prices increase and more dispersed when oil prices decrease. In other words, this will measure changes in trade dispersion[17].

Consider the following gravity equation:

$$T = Y_1^{\beta_1} Y_2^{\beta_2} \mathrm{t} \qquad \text{with} \qquad \mathrm{t} = x^{\beta_3} g^{\beta_4} e^{\beta_5 g^{\alpha_g} x^{\alpha_x}}$$

Where: T is a measure of trade between two regions, the Ys are their GDPs, x is the distance, and g is the oil price. Taking logs ⇒

$$(1) \qquad \ln(T) = \beta_1 \ln Y_1 + \beta_2 \ln Y_2 + \beta_3 \ln x + \beta_4 \ln g + \beta_5 g^{\alpha_g} x^{\alpha_x}$$

[17] Perhaps the term "trade globalization" may also be used, but this term may just be too general. According to Chase-Dunn et al.(2000) trade globalization refers to the overall world openness to international trade.

Here β_3 can be seen as the traditional distance elasticity, β_4 as an overall oil price elasticity, and $\beta_5 g^{\alpha_g} x^{\alpha_x}$ as the interaction term of interest. The variable contains a more general form of $g^{\alpha_g} x^{\alpha_x}$ rather than simply gx.

The percent change in trade given an oil price increase is:

$$(2) \qquad \frac{dln(T)}{dg} = \frac{\beta_4}{g} + \beta_5 \alpha_g g^{\alpha_g - 1} x^{\alpha_x}$$

Then consider two separate distances $\{x_1, x_2 : x_2 > x_1\}$

When oil prices increase, the percent change in trade should be lower/more negative the greater the distance, and so the following must hold:

$$\left.\frac{dln(T)}{dg}\right|_{x_2} < \left.\frac{dln(T)}{dg}\right|_{x_1}$$

This can then be represented as simply taking the derivative with respect to x.

$$(3) \qquad \frac{d\frac{dln(T)}{dg}}{dx} = \frac{d^2 \ln(T)}{dgdx} = \beta_5 \alpha_g \alpha_x g^{\alpha_g - 1} x^{\alpha_x - 1} < 0$$

Because oil price and distance are assumed greater than 0, the condition required for (3) to hold is:

$$(4) \qquad \beta_5 \alpha_g \alpha_x < 0$$

(3) is really a measure of the additional trade decrease in country-pairs[18] that are a unit distance apart. As an example, consider 4 country pairs: CP1 through CP4, and assume that they each fit the gravity equation above. Then consider each having the following distances: CP1 with distance = 1, CP2 with distance = 2, CP3 with distance = 3, CP4 with distance = 4. Further, assume that after an oil price increase, trade decreases for CP1.[19]

[18] A country-pair is a pairing of any two countries.
[19] This is a simplifying assumption to make the language more clear. As can be seen from (2), whether there is an actual decrease in trade is unknown because there are no assumptions made on β_4. As the

Then, (3) implies that trade further decreases for CP2, even more so for CP3, and CP4 will have the highest percent decrease as the pair is furthest apart.

To investigate how trade reacts to the increase in oil price, it is important to first consider β_5. β_5 captures the overall magnitude of the change in trade dispersion due to the change in the oil price. In other words, for a given α_g and α_x, a higher β_5 will imply larger overall changes in trade for the different distances.

Next, it is important to consider α_g and α_x. These by themselves will not measure the overall magnitude of the change in trade dispersion but will instead capture how important high or low values of the oil price are, and whether longer or shorter distances are more important for the changes in trade. In particular, α_g measures the sensitivity to oil price increases. If $\alpha_g = 1$, and there is a dollar increase in oil price, then trade will decrease by the same percentage regardless of the level of the oil price. In other words, the decrease in trade will be the same if oil prices increase from 1 to 2 dollars or 100 to 101 dollars. If $\alpha_g > 1$, then g will be in the numerator of (3) and so the change in trade will be more sensitive when oil prices are high. In this case, there will be a higher relative decrease in trade when oil prices increase from 100 to 101 dollars as opposed to from 1 to 2 dollars. If $\alpha_g < 1$, then g will be in the denominator of (3) and so the change in trade will be greater for when oil prices increase from 1 to 2 dollars. A special case here is when α_g is close to 0, in which case replacing g^{α_g} with $\ln(g)$ will give the same result.[20] Then trade will respond the same to a percent increase in the oil price. In this case, there would be the same trade decrease when oil price doubles from 1 to 2 dollars as when it doubles from 100 to 200 dollars.

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goal of this paper is just to measure trade dispersion as given in (3), the "overall" effect of oil prices is irrelevant here and will be controlled for by year dummies in the regression.

[20] In accordance with the Box-Cox (1964) transformation: $\ln(g) = \lim_{\alpha_g \to 0} (g^{\alpha_g} - 1)/\alpha_g$. Then for when $\alpha_g$is close to 0, the interaction term becomes $\beta_5 x^{\alpha_x} \ln(g) = \beta_5 x^{\alpha_x} (g^{\alpha_g} - 1)/\alpha_g = \beta_5 x^{\alpha_x} g^{\alpha_g}/\alpha_g - \beta_5 x^{\alpha_x}/\alpha_g$. As the model will be estimated using country-pair fixed effects (with year dummies) the results will remain the same. When $\ln(g)$is used, the regression will estimate β_5, and when g^{α_g} is used, the regression will estimate β_5/α_g.

Analogous to α_g, α_x measures the sensitivity of trade to changes in distance; i.e. the rate at which trade decreases due to distance. Here, if $\alpha_x = 1$, then trade decreases by the same additional percent for every unit increase in distance. If $\alpha_x > 1$, then x is in the numerator of (3) implying that the additional percent trade decrease due to distance grows as the distance increases. In other words, the decrease in trade becomes more negative at an increasing rate with distance. If $\alpha_x < 1$, then the additional percent trade decrease diminishes as distance increases. Here the decrease in trade becomes more negative at a decreasing rate with distance. A case to consider is when α_x is close to 0, in which case replacing x^{α_x} with $\ln(x)$ will give the same result. Then the additional percent trade decrease is constant as distance increases *by the percent rather than the level*. Consider the example with the 4 country-pairs above. Define PCT as percent change in trade due to an oil price increase. Then when $\alpha_x = 1$, (PCT of CP1 – PCT of CP2) = (PCT of CP2– PCT of CP3) = (PCT of CP3 – PDT of CP4). When $\alpha_x > 1$, then (PCT of CP1 – PCT of CP2) < (PCT of CP2 – PCT of CP3) < (PCT of CP3 – PCT of CP4). When $\alpha_x < 1$, then (PCT of CP1 – PCT of CP2) > (PCT of CP2 – PCT of CP3) > (PCT of CP3 – PCT of CP4). When α_x is close to 0 then (PCT of CP1 – PCT of CP2) = (PCT of CP2 – PCT of CP4).

2.3.2 Estimation

The goal here is to test if an oil price-distance interaction effect does indeed exist in the real world, and if so, to provide some measure of its magnitude. Therefore, the interaction term $\beta_5 g^{\alpha_g} x^{\alpha_x}$ is incorporated in a standard panel gravity regression, and all that matters is that condition (4) holds with the estimates so that there will be a greater trade decrease (or a lower trade increase) for the longer distance. The regression model is:

$$(5) \quad \ln(T_{ijt}) = \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln x_{ij} + \beta_4 \ln g_t + \beta_5 g_t^{\alpha_g} x_{ij}^{\alpha_x} + \beta_6 g_{t-1}^{\alpha_g} x_{ij}^{\alpha_x} + \beta_7 EMU_{ijt} + \beta_8 CU_{ijt} + \beta_9 FTA_{ijt} + \beta_{10} \ln y_{it} + \beta_{11} \ln y_{jt} + \beta' YEARS + u_{ij} + e_{ijt}$$

where:

The observation unit is country pair i, j for year t. T_{ijt} is the real dollar value of exports from country i to country j in year t. Y_{it} and Y_{jt} are the real GDPs of countries i, j in year t. x_{ij} is the distance between the two countries, g_t is the oil price in year t, and $g_t^{\alpha_g} x_{ij}^{\alpha_x}$ is the interaction variable in question. $g_{t-1}^{\alpha_g} x_{ij}^{\alpha_x}$ is a 1 year lagged interaction variable, and is included because the trade outcomes may be formed sometime after an oil price increase. The distance measure is based on the geographic coordinates of the geographic center of the countries as defined by the CIA World Factbook. The oil price measure is the annual average Brent Crude oil price as reported by the IMF's International Financial Statistics.

In the full specification, additional variables are added that might be correlated with the interaction EMU_{ijt}, CU_{ijt}, and FTA_{ijt}. These are dummy variables for whether the country-pair in question belongs to the eurozone, any other currency union, and/or has a free trade agreement in year t. The eurozone is coded separately, as its effect is much lower in magnitude than other currency unions. $y_{it}, and\ y_{jt}$ are real GDPs per capita; these help control for the countries' capital intensity and the standard of living.[21] $YEARS$ are a vector of dummy variables for each year and are used to control for overall (over all country-pairs) trade effects in year t; these variables control for the effects of all purely year variant variables like g_t. For further details and data sources, see appendix A.

Eq. (5) is estimated by a country-pair fixed effects regression. The fixed effects regression controls for all time invariant pair-specific variables such as distance, culture, common language, common border, etc. In this type of model the overall baseline trade for each country pair is controlled for, and what the regression ultimately looks at is how trade changes over the years within country pairs. For the full specification all world countries are used for years 1952-2012. The presence of α_g and α_x produces a nonlinear model; one possibility for estimation is to use nonlinear least squares (NLLS).

[21] GDP/capita or population was incorporated in early theoretical gravity papers – see Anderson (1979) and Bergstrand (1989).

However, this is not feasible as there are thousands of country-pairs and demeaning is not possible. This study considers another approach; α_g and α_x can be chosen by the researcher so that the model becomes linear and then a simple OLS fixed effects could be run. OLS will minimize the sum of squared residuals given the values for $\alpha_g and\ \alpha_x$. In this paper, different combinations of $\alpha_g, and\ \alpha_x$ are manually chosen until one combination (jointly with all the other beta estimates) produces the lowest possible sum of squared residuals. With this procedure, OLS tests to see if the best possible fit for the interaction variable is significant and provides a magnitude of its impact. Further, as the goal of NLLS is to minimize the SSR, this will produce the same coefficient estimates as running NLLS.[22]

2.4 Results

2.4.1 Specifications

The results from the panel gravity regression are shown in Table 2.1. All specifications include year dummies. Specification 1 is a baseline traditional gravity equation that includes distance and incomes without country pair fixed effects. Specification 2 is a baseline fixed effects gravity regression; here distance is dropped as it is time invariant. Specification 3 includes the interaction term in question. $\widehat{\alpha_g}$ and $\widehat{\alpha_x}$ are chosen within .05 accuracy, and are reported at the top. Here $\widehat{\beta_5}$ = -2.091 and is highly significant, indicating that there is indeed an interaction effect. $\widehat{\alpha_g}$ and $\widehat{\alpha_x}$ are both negative, however condition (4) holds with the estimates, meaning that an increase in the oil price will produce a smaller/more negative trade effect for longer distances. The rest of the specifications also reveal that interaction term is with the correct sign and significance. The magnitude interpretation of these coefficients will be discussed in the next subsection. Specification 4 includes all the variables from the full model in eq. (5) without the lagged interaction. Note that the eurozone dummy is negative and insignificant – more on this in section 2.6. Specification 5 has a lagged interaction added and is considered to be the model in eq. (5). Here the lagged

[22] This is confirmed with a small sample.

interaction has a coefficient of lower magnitude and significance than that of the contemporaneous.

As can be seen in Figure 2.1, after rising sharply in the 1970s and falling in the 1980s, oil prices have substantially increased in the 2000s. As a robustness check, regressions 6 and 7 split the data at 1992 - each including the full model. 1992 is chosen because that is the period when the world became more open to trade due political changes in Eastern Europe and the collapse of the Soviet Union.

It is known that this type of regression suffers from the many zeros problem in trade. 45% of the observations have 0 trade, and thus drop when the log is taken. As a fix, the final specification runs the regression with pairwise combinations of 60 large trading countries for all years. The countries used are summarized in Appendix B. In this sample only 10% of the observations have 0 trade. Further, the selected sample only makes up 11% of all observations, but constitutes over 75% of the traded value.

2.4.2 Robustness

For further robustness checks, different measures for the oil price and distance are used with all the specifications from Table 2.1. These measures for oil are the Brent Crude, West Texas Intermediate, and Dubai Fateh, which in Figure 2.1 all appear to be highly similar in their annual averages. A second distance measure, a measure from the capitals of the countries, is also included. This is also calculated from coordinates of the capitals, provided by the CIA World Factbook. The results show that any combination between a distance measure and an oil price measure leads to specification results highly similar to Table 2.1. Further, instead of 1992, different year splits are used from the 80s and 90s with combinations of the different distance and oil price measures. The results are again significant everywhere and are of similar magnitude to the year splits of Table 2.1.

2.4.3 Meaning of Coefficients

Table 2.1 and the robustness checks conclude that an increase in the oil price will relatively decrease trade by more for longer distances. With the estimates obtained, one can easily obtain magnitudes of the decrease. First, consider an oil price change from g_{t-1} to g_t. Then define $\Delta ln(T_t^{x_i}) = ln(T_t^{x_i}) - ln(T_{t-1}^{x_i})$ to be the percent change in trade for a country pair with distance x_i between periods $t-1$ and t. Then consider two country pairs with distances: $\{x_1, x_2\}$. As a measure of how trade changes relative to the different distances one can use the difference between the two trade changes. In this case, consider Eq. (1) and define D to be a measure of a change in trade dispersion:

$$D = \Delta ln(T_t^{x_2}) - \Delta ln(T_t^{x_1}) = \beta_5 x_2^{\alpha_x}(g_t^{\alpha_g} - g_{t-1}^{\alpha_g}) - \beta_5 x_1^{\alpha_x}(g_t^{\alpha_g} - g_{t-1}^{\alpha_g})$$
$$= \beta_5(x_2^{\alpha_x} - x_1^{\alpha_x})(g_t^{\alpha_g} - g_{t-1}^{\alpha_g})$$

If there is an oil price increase, and $x_2 > x_1$, then *D* should be negative and trade becomes more localized. In this case when getting rid of the logs, the actual relative percent decrease in trade can be obtained by $100 * \left(1 - \frac{T_t^{x_2}/T_{t-1}^{x_2}}{T_t^{x_1}/T_{t-1}^{x_1}}\right) = 100 * (1 - e^D)$. On the other hand, if there is a decrease in the oil price, then the more distant country pair should increase trade by more (implying a positive D) and trade becomes more dispersed.

Specifications (5) through (8) in Table 2.1 also include a lagged oil interaction term. This implies that a permanent increase in the oil price will fully impact trade after two years. The full impact on trade is $ln(T_t^{x_i}) - ln(T_{t-2}^{x_i})$. Then for this case:

$$\Delta ln(T_t^{x_2}) - \Delta ln(T_t^{x_1}) = (x_2^{\alpha_x} - x_1^{\alpha_x})(\beta_5(g_t^{\alpha_g} - g_{t-2}^{\alpha_g}) + \beta_6(g_{t-1}^{\alpha_g} - g_{t-3}^{\alpha_g}))$$

Now assume that in periods $t-2$ and $t-3$ oil prices are the same, and then there is permanent increase in oil price starting in $t-1$. Then the above can be simplified: $g_{t-2}^{\alpha_g} = g_{t-3}^{\alpha_g}$, and $g_{t-1}^{\alpha_g} = g_t^{\alpha_g}$, and simply adding β_5 and β_6 will give the full impact after 2 years.

Given the estimates from Table 2.1, a way to interpret the coefficients on the interaction is to look at how predicted trade changes when the distance is some x miles relative to when the distance is 0 miles (this can be given by the measure D). The problem is that $\widehat{\alpha_x}$ is negative for many specifications, and so one cannot divide by a distance of 0 as this implies an infinitely larger decrease in trade when compared to any other distance. The shortest distance in the sample is 46 miles from St. Lucia to St. Vincent, and there are a total of 12 country pairs with a distance less than 100 miles. Therefore, a reasonable baseline of 100 miles will be used to compare how trade changes for the different distances. The units for distance are 1 for 10,000[23] miles. The units of oil price are in dollars per barrel (in 2005 dollars) as given in Figure 2.1. Then for the change in the oil price, assume that the oil price decreases by half from its sample mean. In this case the means for the full sample, after 1991 and before 1992, are 30, 40, and 24 dollars per barrel, respectively. Table 2.2 shows how trade decreases at different distances for the different specifications in Table 2.1. For example, for specification 4, assume an oil price decrease from 30 dollars to 15 dollars a barrel. Then, the column shows the different measures of D (in percent changes) for different distances relative to the 100 mile baseline. For a distance of 1000 miles: $D = -1.389(.1^{-.3} - .01^{-.3})(15^{-.25} - 30^{-.25}) = .223$ and the percent change is then: $100 * (e^{.223} - 1) = 24.98$. Specifications 3 and 4 only show the 1 period effect, as no lags are included. Specifications 5-8 include a lag and the effect shown is the full two year effect on trade. For these specifications assume that $g_{t-2}^{\alpha_g} = g_{t-3}^{\alpha_g}$, and $g_{t-1}^{\alpha_g} = g_t^{\alpha_g}$ so that adding the $\beta_5\ and\ \beta_6$ will give the full impact.

The overall impression of Table 2.2 is that oil prices do indeed alter the behavior of trade with substantial effects. Based on the regressions, the magnitudes appear to be significant and large. For example, in the full specification an oil price halving will make trade more dispersed by increasing trade around 40% for a distance of 10,000 miles and by 25% for a distance of 1000 miles (relative to the 100 miles baseline). Further, almost all regressions show that $\widehat{\alpha_x} < 0$, suggesting that there would not be much of a

[23] So .01 represents 100 miles (the baseline).

difference in the change in trade for very long distances. Perhaps this is because cargo usually travels mostly by ship for long distances and by truck or rail for shorter distances. Cargo transportation (that is not by air) is much cheaper across water by ship than by land with a truck – see Gilbert and Perl (2013). A rise in oil prices will thus affect shipping by land much more and this will contribute to the largest increase in the price.

Table 2.3 shows the impact of historic oil price movements. The first is the drastic increase during 1970s, while the second is the decrease that followed in the 1980s; both use the estimates before 1992 (specification 7). The third is the recent oil price increase in the 2000s and uses the estimates after 1992 (specification 6). Based on this information, it appears that the drastic oil price increase since 2000 has had substantial effects in that world trade has become significantly more localized, implying a 35% relative trade decrease for 1000 miles, and a 50% decrease for 10,000 miles.

2.5 The General Equilibrium (GE) Gravity Model

2.5.1 The Model

This section will incorporate the interaction term into a more modern version of the gravity model. In this version, the gravity model takes into account general equilibrium effects, such as trade diversion. This result has theoretical foundations in Anderson and van Wincoop (2003).[24] The paper uses the AvW general equilibrium model which produces the following gravity equation:

$$(6) \qquad T_{ij} = \frac{Y_i Y_j}{Y_w} \left(\frac{t_{ij}}{P_i P_j} \right)^{1-\sigma} \quad \forall i, j \quad \sigma > 1$$

where:

$$(7) \qquad \mathrm{P}_j^{1-\sigma} = \left(\sum_i \frac{\theta_i {t_{ij}}^{1-\sigma}}{\mathrm{P}_i^{1-\sigma}} \right) \quad \forall j$$

[24] Also see Anderson (1979), Bergstrand (1985,1989), and Deardorff (1998) for similar derivations.

In this model, T_{ij} again represents the value of exports from country *i* to country *j*, Y_i, Y_j represent the GDPs of i, j. $t_{ij} = t_{ji}$ are the trade costs between i, j. Y_w is world GDP, and $\theta_i = Y_i/Y_w$ is country *i*'s world GDP share. P_i, P_j are known as the multilateral resistances (MRs) of countries i and j. These are what make GE gravity equation different from the traditional gravity equation. Both P_i and P_j are country specific and depend on the trade costs and GDPs. They represent the overall trade costs associated with the particular country, and so as t_{ij} increases P_i, P_j also increase. From eq. (7), the MRs can be solved for given values of GDPs, trade costs, sigma and a computational program. A summary of the model and its theoretical predictions regarding the impact of oil price is available in Appendix C.

2.5.2 Estimation

The GE gravity model in (6) can be applied to panel data and estimated. The additional variables implied by GE gravity are the MRs - $\ln(P_{it})$ and $\ln(P_{jt})$. Not including the MRs in the regression will bias the coefficient on trade costs upward. In other words, the coefficient estimates should really be more negative. This is because trade costs are positively correlated with MRs, and MRs are positively related to trade[25]. However, in its application the MRs cannot be easily solved for. Therefore, country-year specific dummy variables are used to control for the MRs and any other country specific factors. In particular, each dummy is equal to 1 for the particular year and the particular country, 0 otherwise. Because some countries are not included for certain years, the number of dummies is only roughly equal to the number of countries times the number of years. The dummies also control for all year specific effects. The full model thus becomes:

$$(8)\quad \ln(T_{ijt}) = \beta_1 g_t^{\alpha_g} x_{ij}^{\alpha_x} + \beta_2 g_{t-1}^{\alpha_g} x_{ij}^{\alpha_x} + \beta_3 EMU_{ijt} + \beta_4 CU_{ijt} + \beta_5 FTA_{ijt} + \beta' Country - Year + u_{ij} + e_{ijt}$$

[25] Mathematically if the variable $\ln(P_{it})$ is not included in the regression then the sign of bias on the coefficient of trade costs = $cov(\ln(t_{ijt}), (\sigma - 1)\ln(P_{it}))$>0.

(8) is somewhat difficult to estimate with the full country sample. The dataset contains over 200 countries and 60 years. Having to add this many dummy variables will easily amount to over 80GB of data and possibly require days of computation for a single regression. To simplify computations, only the sample of selected countries in Appendix B is used.

Table 2.4 reports estimates of (8) using a panel fixed effects regression. The first regression is (8) with the contemporaneous interaction term. The second is the full specification and includes both the contemporaneous and lagged interaction terms. The third is again the full specification, but uses the alternative distance measure from capital to capital. The fourth specification is more general in that it includes importer-year and exporter-year dummy variables. For each year, each country has a dummy for when it is an exporter, and a separate dummy when it is an importer. This is done because the assumption that trade costs are symmetric may not hold. In this case the model becomes equation (7c) from Appendix C, and for each year, the importer and exporter dummies are controlling for $P_j^{1-\sigma}, P_i^{1-\sigma}, \Pi_j^{1-\sigma}$, and $\Pi_i^{1-\sigma}$.

Overall the results are consistent with theory in that condition (4) holds with the estimates and the coefficient in-front of the interaction term is highly significant. Including the country-dummies helps remove the omitted variable bias. However, although the coefficients are not biased, they no longer represent the impact on trade. If the impact gives information as to how trade changes when trade costs change (all else constant), it is important to remember that the MRs are also functions of the trade costs. For example, consider the log of Eq. (6) and the derivative with respect to trade costs:

$$(9) \qquad \frac{\mathrm{dln}\, T_{ij}}{\mathrm{dln}\, t_{ij}} = (1-\sigma)\left(1 - \frac{\mathrm{dln}\, P_i}{\mathrm{dln}\, t_{ij}} - \frac{\mathrm{dln}\, P_j}{\mathrm{dln}\, t_{ij}}\right)$$

If impact is defined as $\frac{\mathrm{dln}\, T_{ij}}{\mathrm{dln}\, t_{ij}}$, then clearly this depends on how the MRs change in response to the trade costs. Therefore, $\frac{\mathrm{dln}\, T_{ij}}{\mathrm{dln}\, t_{ij}}$ will vary by country-pair. It is known that if

$\frac{\mathrm{dln}\,P_j}{\mathrm{dln}\,t_{ij}}$ and $\frac{\mathrm{dln}\,P_i}{\mathrm{dln}\,t_{ij}} > 0$, then the impact of trade costs is not as negative as represented by the coefficient $(1-\sigma)$ alone. In summary, not controlling for the MRs will bias the coefficient upwards; however when they are controlled for, the impact should really be less negative than represented by the coefficient estimate.

2.5.3 The GE Impact Of Oil Prices

The GE gravity model predicts that total world trade will stay the same when trade costs change and there is only a trade redistribution effect. For example, as oil prices decrease, world trade becomes more dispersed, internal trade (consumption of own good) decreases, and world international trade increases.

It is somewhat difficult to obtain the actual impact of oil prices on trade based on the coefficient estimates. Oil price will change relative trade costs for the whole world and it is therefore essential to account for worldwide MR changes. Glick and Taylor (2010) propose to first obtain the coefficient estimates using a regression, and then to apply the estimates directly to the GE gravity equation in (6) using a 3 step procedure. Step 1 is to use (6) to solve for the trade costs (${t_{ij}}^{1-\sigma}$) and MR terms (${P_i}^{1-\sigma}, {P_j}^{1-\sigma}$) using given data on export levels (T_{ij}) and GDPs (Y_i, Y_j). There is a slight problem here in that there are more unknowns than equations. To solve this problem, Glick and Taylor (2010) set all internal trade costs (${t_{ii}}^{1-\sigma}$) equal to 1. Then the MRs[26] can easily be solved from the internal trade equations (T_{ii}) in (6), and then the rest of the trade costs (the international trade costs) can be solved from the rest of the trade equations. Step 2 is the implementation of a policy[27] that changes the trade costs, and the recalculation of the MRs using (7). In step 3, (6) is used to obtain the counterfactual export levels given the new trade costs, MRs, and the same GDPs. The ratio of the actual to the counterfactual export level is then used to calculate the impact of the policy. An

[26] For this process, solving for MRs and the other variables refers to solving for them raised to the $1-\sigma$. Therefore, no assumptions on σ are made.
[27] Policy means anything that alters the trade cost structure. In this paper it is the oil price-distance interaction term. In particular, what is considered is how the trade costs will respond when oil prices decrease by half. Later in the paper, the Eurozone will be examined and the policy will be a hypothetical removal of the Eurozone, which will increase the trade costs within the countries of the Eurozone.

ostensible problem is that step 1 assumes t_{ii} is set to 1. However, Appendix D shows that it does not matter what the internal trade costs are set to; in the end the counterfactual export level will be the same.

For the calculation of the impact, it is necessary to know the state of the world – in terms of GDPs and trade levels. In this case the thought experiment is to see how a halving of the oil price at 2012 (last year of sample) will increase exports. The countries used are the selected country sample in Appendix B. In 2011 and 2012 the oil price was roughly $92. The interest is in the full two year impact when oil price halves to $46 dollars. (6) predicts that $T_{ij} = T_{ji}$. To be consistent with the model, instead of using export levels, the averaged trade is used, calculated from the data as $T_{ij}^a = T_{ji}^a = \frac{T_{ji}+T_{ij}}{2}\ \forall\ i,j$. Then in implementing the steps 1-3: GDPs and the averaged trade levels are known for all countries in 2012, while internal trade is calculated as:

$$T_{ii}^a = Y_i - \sum_{\substack{j \\ j\neq i}} T_{ij}^a \quad \forall i$$

Further, as step 1 suggests, the trade costs are calculated from the trade levels and GDPs. Step 2 requires estimates of the parameters. For the estimates, it is important to have a recent sample to capture the oil price increase since 2000 along with country specific dummies so that the estimates are the most consistent with the model. Here the estimates come from Table 2.7, specification 6, which reports results for (8) after 1992. The trade costs can be seen as having the following structure: ${t_{ijt}}^{1-\sigma} = other_{ijt} * e^{\beta_1 g_t^{\alpha_g} x_{ij}^{\alpha_x} + \beta_2 g_{t-1}^{\alpha_g} x_{ij}^{\alpha_x}}$. Where $other_{ijt}$ represents any other trade costs not related to oil prices, and $e^{\beta_1 g_t^{\alpha_g} x_{ij}^{\alpha_x} + \beta_2 g_{t-1}^{\alpha_g} x_{ij}^{\alpha_x}}$ are the oil price interaction components in (8). Next, applying the estimates ⇒ ${t_{ij2012}}^{1-\sigma} = other_{ij2012} * e^{-.2321*92^{-.1}x_{ij}^{-.7}}$. Now after a hypothetical decrease in the oil prices (all else constant) the trade costs become ${t_{ijNEW}}^{1-\sigma} = other_{ij2012} * e^{-.2321*46^{-.1}x_{ij}^{-.7}} = {t_{ij2012}}^{1-\sigma} * e^{-.2321*(46^{-.1}-92^{-.1})x_{ij}^{-.7}}$. In this case the 2012 trade costs (as computed in step 1) are multiplied by

$e^{-.2321*(46^{-.1}-92^{-.1})x_{ij}^{-.7}}$ to form the after policy trade costs. This multiplication requires knowledge of internal distances (x_{ii}) for the computation of ${t_{iiNEW}}^{1-\sigma}$. For simplicity, these are calculated as just the square-root of the total country area. Once the after policy trade costs are obtained, (7) is used to recalculate the MRs using MATLAB. Finally in step 3, the counterfactual trade levels are obtained using (6) with the new MRs and trade costs.

2.5.4 GE Impact Results

For each country-pair the actual averaged trade levels[28] are compared to the counterfactual averaged trade levels. Then the percentage change in trade for each country pair is calculated as $100 * (\frac{counterfactual\ T_{ij}^{a}}{actual\ T_{ij}^{a}} - 1)$. Table 2.5 shows the percent change in trade for the top 15 trading nations. The decrease in internal trade is then given on the diagonals. The overall percentage change in international trade for each country is available at the end of each column, and is calculated from the ratio of total counterfactual international trade to the total actual international trade for each country (from all other 56 countries). From the table, it appears that the largest increases will be in the UK, Canada, Japan, and South Korea. This is consistent with theory in that these countries tend to be isolated, and so they will have the largest reductions in the trade costs with the other countries. Then the overall world international trade increase is calculated from the ratio of total counterfactual trade to the total actual international trade from all countries. It appears that the overall world trade will increase by roughly 3%. The magnitudes do appear less than most specifications in Table 2.2, but here only the selected country sample is used. The selected country sample in the traditional gravity regressions (specification 8) also produced lower magnitudes.

[28] Actual trade levels refer to the 2012 trade levels before the hypothetical oil price decrease. The counterfactual trade levels refer to the trade levels after the hypothetical oil price decrease.

2.6 Application: The Eurozone Effect on Trade

Adding an oil price-distance interaction term in the gravity model might have many applications. One application is a more accurate estimate of the eurozone effect on trade (within countries of the eurozone). As shown above, there is clear evidence that oil prices cause changes in trade dispersion. The conclusion is that in times of increasing oil prices, countries will increase trade more with their neighbors relative to countries further away; in other words, trade will become more localized. Because the EMU creation corresponded with the major oil price increase since 1999 and the countries of the EMU tend to be closer together, the interaction can partially explain why trade increased more in the EMU compared to country pairs not in the EMU. Hence, this implies that the true eurozone effect should be less than originally estimated.

2.6.1 Literature Review

The eurozone effect on trade falls under the umbrella of estimations used to estimate the effects of currency unions on trade. Theoretically, currency unions help increase trade as they eliminate currency exchange costs and exchange rate risk while providing greater price transparency. The widely-cited paper of Rose (2000) estimates the currency union effect on trade from all possible worldwide currency unions. To do this, Rose adds a currency union dummy variable to a cross-sectional gravity regression. The variable is equal to 1 if the country-pair belongs in a currency union and 0 otherwise. The coefficient in-front of the dummy variable suggests that countries in currency unions trade as much as three times with each other than country pairs not in currency unions – this is known as the Rose effect. However, cross-sectional regressions are generally weaker than panel fixed effects regressions in that the latter control for all time invariant country pair unobservables. In this case the panel fixed effects regression looks at the effect of when countries enter and leave a currency union. In a follow up paper Glick and Rose (2002), Rose acknowledges that because he had a cross section gravity model he was answering the question: "How much more do countries within currency unions trade than non-members?" when the more appropriate question to answer: “What is the trade effect of a country joining (or leaving) a currency union?” is answered using a panel fixed effects model.

One of the first papers to explore the eurozone effect on trade is Micco, Stein, and Ordenez (MSO, 2003). As in Glick and Rose (2002), MSO also use a panel fixed effects gravity regression (with year dummies) for years 1992-2002, but with a eurozone dummy variable instead. MSO use 22 countries - half are members of the eurozone and half are industrialized countries outside the eurozone. For this particular estimation, the coefficient on the eurozone dummy behaves like a difference in differences estimate. It more or less compares the change in trade of the eurozone countries before and after 1999 to that of the other industrialized countries before and after 1999. After controlling for certain key variables, the coefficient estimate of the eurozone dummy suggests that the country-pairs in the eurozone had their bilateral trade increase 5-10% more compared to country-pairs not in the eurozone.

A more recent paper Frankel (2010), expands the dataset used by MSO (2003) for years 1992-2006 and runs the same panel gravity model. He obtains slightly higher results in that the effect of the EMU on trade is roughly 10%. However, Frankel expands the dataset once more to include all world countries between 1945-2006. The results then show that the coefficient on EMU is roughly .9. This is similar in magnitude to the effect estimated by Rose (2000); however, using such a large sample may contain many time varying unobservables, and also compares the eurozone countries to many third world combinations. For example, it is known in the trade literature that over the past 50 years, trade patterns have changed from mainly North-South to North-North trade.

Baldwin and Taglioni (2007) also use the methodology of MSO (2003), however they apply the AvW - GE gravity model and include country-year dummies to control for the multilateral resistance terms. After the dummies are included, the coefficient turns significantly negative. Perhaps a weakness of their paper is that only the sample of industrialized countries is used. This might not be fully appropriate as the theoretical results of the AvW model require all trading partners. Thus, using only the industrialized countries will not fully control for the multilateral resistance terms.

Other papers that estimate the EMU impact use less traditional approaches. Berger and Niche (2008) uses long run data to study the effect of the Euro currency on trade. Once a time trend on trade for the EMU 11 is used, the EMU impact is insignificant. Bun and Klaassen (2007) allow for country-pair specific time trends that also produce insignificant results. Flam and Nordstram (2006) use bilateral exports as their dependent variable of choice. The exports are also broken down by sector to show which sectors benefited the most from the trade. Nardis and Vicarelli (2003) use a dynamic first differenced gravity model. The main results obtained from all papers are summarized in Table 2.6.

2.6.2 Traditional Gravity Estimation and Results

The eurozone effect on trade in this research is estimated using the traditional gravity methodology of the above papers. In particular, to be consistent with the literature, eq. (5) is estimated by panel fixed effects using only the industrialized countries, years 1992-2012, and an additional (country specific) real effective exchange rate variable. The panel fixed effects estimation with year dummies compares how trade changes in the countries of the eurozone to how trade changes in the countries outside the eurozone before and after 1999 (except for country-pairs that include Greece). Including recent years (since 1992) is important, as the EMU estimate is more or less a difference in differences estimate. For a fair comparison, only the industrialized countries from Appendix B are included. If, for example, all the countries of the European Union are included, the coefficient on the EMU dummy is significantly negative. This is because trade with Eastern Europe has drastically increased since 1999. Likewise, trade with many less developed nations has also drastically increased since 1999. If all world countries were included, specification 6 from Table 2.1 suggests that the eurozone decreased trade by more than 10%.

Table 2.7 shows the eurozone effect before and after including the oil price interaction variable. Specifications 1-4 are the traditional estimations and include the industrialized countries only. Specification 1 does not take into account oil prices and suggests that the eurozone effect is $(e^{.0941} - 1) * 100 = 9.87\%$. After the oil-price interaction term is included, specification 2 suggests that the eurozone effect falls to 6.82%. Specification 3 uses the alternative distance measure, and 4 includes a lagged interaction term. Their estimates also imply a eurozone effect of around 7%.

2.6.3 GE Gravity Estimation and Results

The AvW – GE gravity model may also be applied in estimating the eurozone effect on trade. The theoretical model requires all trading partners; therefore using just the industrialized countries is not fully appropriate for this estimation, as this will not fully control for the MRs.[29] However as stated above, the problem with including all countries is that since 1999 trade increased by a larger factor with many less developed countries, and therefore caused the eurozone effect to turn negative. The good news with this estimation is that it uses country-year dummies. Besides controlling for the multilateral resistance terms, they also control for country specific trade changes over time. When less developed countries are included, the dummies are able to control for their drastic trade increase with the rest of the world, thus allowing for a fair comparison. Therefore, the sample for this estimation is all the countries of Appendix B.

To estimate the EMU coefficient, variations of (8) after 1992 are used. The results are reported in Table 2.7, specifications 5-8. To control for the multilateral resistance terms (and country specific trade increases), specifications 5 and 6 include country-year dummy variables. The coefficient estimates without the interaction term are reported in specification 5, while the estimates with the interaction term are reported in specification 6. When trade cost symmetry is not assumed, the model requires exporter-year and importer-year dummies to control for the multilateral

[29] When only the industrialized countries are included with country-year dummies, the coefficient on EMU is very close to 0 and insignificant. Baldwin and Taglioni(2007) even have a significantly negative coefficient.

resistance terms. The results using these controls are reported in specifications 7 and 8. The coefficient estimates are roughly similar across the four specifications. As can be seen, the eurozone coefficient drops by approximately a third once the oil-price interaction is included.

These coefficient estimates only show how the trade costs change, but not the full trade impact. To my knowledge, no other study has shown the full trade impact based on the AvW model. The impact should actually be lower than 7% because the addition of the eurozone will decrease trade costs which will in-turn lead to a decrease in the MR terms for the eurozone members. To obtain the actual impact of the eurozone on trade, the three step procedure from section 2.5 is used. The thought experiment is to see how trade changes when the eurozone no longer exists. To be most consistent with the model, the estimate from specification 6 is used. From step 1, the same 2012 trade costs as section 2.5 are calculated from the trade levels and GDPs. In step 2, the calculated trade costs from step 1 can be seen as having the following structure: ${t_{ijt}}^{1-\sigma} = other_{ijt} * e^{\beta_3 EMU_{ijt}} \Longrightarrow {t_{ij2012}}^{1-\sigma} = other_{ij2012} * e^{.0703*EMU_{ij2012}}$. Where $other_{ij2012}$ are all the other trade costs not including the benefits from the eurozone. Then clearly these other trade costs are the new trade costs when the eurozone no longer exists $\Longrightarrow {t_{ijNEW}}^{1-\sigma} = other_{ij2012} = {t_{ij2012}}^{1-\sigma} / e^{.0703*EMU_{ij2012}}$. Once the new trade costs are obtained, (7) is used to recalculate the new MR terms. Once the new MR terms are obtained, (6) is used to obtain the counterfactual trade level. For each country pair the ratio of the counterfactual to the actual trade is used to calculate the impact of the eurozone for the specific country pair. Table 2.8 summarizes how trade will decrease between the eurozone members once the benefit from the eurozone is removed. The end of the columns report how each country will lose from the removal of the eurozone; this is calculated from the ratio of counterfactual to actual trade for each country with only all the other eurozone members. As can be seen, for most members the loss in trade is around 5%. Finally, for what can perhaps be called the eurozone effect from the GE model, the last number gives information of how the total trade from the eurozone changes; this is calculated from the ratio of counterfactual to actual total trade from only all the eurozone members. This value is again around 5%.

2.7 Conclusion

This study incorporates an oil price-distance interaction variable in a large panel gravity regression to show that oil prices cause changes in global trade dispersion. In other words when oil prices rise, trade becomes more localized, and when they fall, trade becomes more dispersed. According to Table 2.3, the magnitudes are reasonably large in that the oil price increase in the 1970s relatively reduced trade by 10% for countries 1000 miles apart, and 30% for countries 10,000 miles apart. On the other hand, the increase since the late 1990s has led to an even more substantial localization in the order of a 35% relative decrease for 1000 miles, and a 50% decrease for 10,000 miles. Based on this information, in times of decreasing oil prices, the more isolated countries benefit more (in terms of international trade increases), but are relatively worse off in times of increasing oil prices as their trade decreases the most. These are all big picture results; some basic extensions may include: splitting goods into product categories based on weight to value ratio, or perhaps controlling for mode of transportation as shipping is much more fuel intensive by air than by water (Gilbert and Perl, 2013, Table 4.15).

The results presented here can in turn shed more light on the characterization of trade costs, and in particular their time varying component. The application in this paper concludes that the oil price-distance interaction reduces the eurozone effect on trade by roughly a third, and up to a half when calculating the general equilibrium impact. In recent years the existence of the eurozone has come into question. The eurozone did increase trade, but not to the extent previously thought. Perhaps this paper provides more reason to doubt the benefits of the currency union.

In current times, crude oil continues to be a driving force behind world transportation. According to IEA (2012) – World Energy Outlook, petroleum will still be the driving force by 2035, supplying 87% of the world’s energy transportation needs.

Further, oil has an expected demand growth by roughly 1% per year, but conventional world oil production is expected to remain roughly constant through the year 2035. Given these circumstances, an increased price and volatility of crude oil is highly likely in the future (Hamilton, 2008, Owen et al., 2010), and therefore the results from this study will remain important.

Table 2.1 Traditional Gravity Estimates (1952-2012)

Alpha Coefficients	1 standard	2 fixed effects	3 interaction	4 full	5 lagged interaction	6 year>1991	7 year<1992	8 selected all years
α_g			**-0.25**	**-0.25**	**-0.2**	**-0.95**	**-0.2**	**-1.2**
α_x			**-0.25**	**-0.3**	**-0.3**	**-0.25**	**0.45**	**0.35**
Beta Coefficients								
$g_t^{\alpha_g} x_{ij}^{\alpha_x}$			**-2.091*** **	**-1.389*** **	**-1.182*** **	**-4.997*** **	**1.996*** **	**15.67*** **
			(-10.93)	**(-9.699)**	**(-7.153)**	**(-6.602)**	**(4.495)**	**(6.803)**
$g_{t-1}^{\alpha_g} x_{ij}^{\alpha_x}$					**-0.298***	**-2.545*** **	**0.505**	**-6.103** **
					(-1.810)	**(-3.900)**	**(1.106)**	**(-2.502)**
GDP 1	1.018***	0.266***	0.266***	-0.207***	-0.199***	0.224***	-0.713***	0.209**
	(138.6)	(21.48)	(21.55)	(-4.356)	(-4.180)	(3.000)	(-9.941)	(2.182)
GDP 2	0.819***	0.213***	0.212***	0.707***	0.715***	1.041***	0.288***	0.816***
	(118.4)	(18.84)	(18.92)	(16.76)	(16.92)	(17.11)	(4.587)	(10.36)
GDP/Capita 1				0.471***	0.467***	0.164**	0.823***	0.0878
				(10.43)	(10.32)	(2.235)	(11.68)	(0.968)
GDP/Capita 2				-0.495***	-0.501***	-0.607***	-0.157**	-0.491***
				(-12.08)	(-12.19)	(-9.770)	(-2.546)	(-6.909)
CU				0.816***	0.808***	-0.0887	0.783***	1.027***
				(7.968)	(7.888)	(-0.167)	(8.815)	(4.191)
EMU				-0.00694	-0.00635	-0.102***		-0.195***
				(-0.147)	(-0.135)	(-3.526)		(-3.448)
FTA				0.469***	0.463***	0.193***	0.573***	0.156***
				(9.993)	(9.925)	(4.431)	(7.673)	(3.010)
Distance	-1.277***							
	(-85.58)							
Country-pair Fixed Effects	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	669,429	669,429	669,429	669,429	668,075	395,000	273,075	135,114

Year dummies included in all, Cluster-robust t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 2.2 Meaning of Coefficients

Table 1 Specification	3	4	5	6	7	8
Full Interaction	$\mathbf{-2.091 g_t^{-.25} x_{ij}^{-.25}}$	$\mathbf{-1.389 g_t^{-.25} x_{ij}^{-.3}}$	$\mathbf{-1.48 g_t^{-.2} x_{ij}^{-.3}}$	$\mathbf{-7.542 g_t^{-.95} x_{ij}^{-.25}}$	$\mathbf{2.501 g_t^{-.2} x_{ij}^{.45}}$	$\mathbf{9.567 g_t^{-1.2} x_{ij}^{.35}}$
Oil price change ($)	30 to 15	30 to 15	30 to 15	40 to 20	24 to 12	30 to 15
With Lag	No	No	Yes	yes	yes	yes
Distance (miles)	Percent increase in predicted trade when oil price is halved (relative to 100 miles benchmark)					
200	8.88	8.76	8.69	11.22	0.91	1.10
400	16.95	16.43	16.30	21.62	2.17	2.53
600	21.29	20.43	20.26	27.28	3.12	3.55
800	24.20	23.06	22.87	31.11	3.92	4.37
1000	26.36	24.98	24.78	33.97	4.61	5.07
2000	32.55	30.35	30.10	42.22	7.32	7.69
4000	37.99	34.88	34.58	49.55	11.14	11.11
6000	40.85	37.19	36.87	53.43	14.08	13.60
10000	44.13	39.76	39.42	57.91	18.79	17.39

Table 2.3 Impact of Historic Oil Price Changes

Full Interaction	$\mathbf{2.501} g_t^{-.2} x_{ij}^{.45}$	$\mathbf{2.501} g_t^{-.2} x_{ij}^{.45}$	$\mathbf{-7.542} g_t^{-.95} x_{ij}^{-.25}$
Historic period	1973-1980	1980-1986	1999-2008
Real oil price change	\$12 to \$77	\$77 to \$23	\$21 to \$90
Distance (miles)	Percent change in predicted trade (relative to 100 miles benchmark)		
200	-2.15	1.33	-14.58
400	-5.02	3.18	-25.18
600	-7.11	4.58	-30.07
800	-8.80	5.75	-33.07
1000	-10.25	6.79	-35.18
2000	-15.59	10.84	-40.68
4000	-22.38	16.62	-44.94
6000	-27.09	21.14	-46.99
10000	-33.83	28.49	-49.20

Table 2.4 General Equilibrium Gravity Model Estimation (1952-2012)

	1	2	3	4
Alpha Coefficients	Baseline	Lagged Interaction	Alternative Distance	Exporter/Importer Dummies
$\boldsymbol{\alpha_g}$	**-1.05**	**-1**	**-1**	**-1**
$\boldsymbol{\alpha_x}$	**-0.1**	**-0.1**	**-0.1**	**-0.15**
Beta Coefficients				
$\boldsymbol{g_t^{\alpha_g} x_{ij}^{\alpha_x}}$	**-20.08*** **	**-13.02*** **	**-12.71*** **	**-7.483*** **
	(-6.480)	**(-4.227)**	**(-4.258)**	**(-4.117)**
$\boldsymbol{g_{t-1}^{\alpha_g} x_{ij}^{\alpha_x}}$		**-5.326* **	**-5.493* **	**-3.681** **
		(-1.801)	**(-1.885)**	**(-2.150)**
CU	0.775***	0.755***	0.766***	0.804***
	(3.381)	(3.293)	(3.303)	(3.739)
EMU	0.0581	0.0608	0.0709	0.0639
	(0.919)	(0.968)	(1.128)	(1.103)
FTA	0.435***	0.430***	0.426***	0.425***
	(9.075)	(9.016)	(8.912)	(9.941)
Country-Year Dummies	Yes	Yes	Yes	No
Observations	158,658	156,959	156,959	156,959

Country-pair fixed effects in all
Cluster-robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.5 GE Gravity Model Percent Change In Trade (due to oil price halving from 92 to 46 for top 15 trading countries)

	United States	United Kingdom	France	Germany	Italy	Netherlands	Canada	Japan	Spain	Hong Kong	India	South Korea	Singapore	Russia	China
United States	-0.3														
United Kingdom	5.3	-1.1													
France	3.8	1.8	-0.6												
Germany	4.7	1.9	-0.1	-0.9											
Italy	5.1	5.6	1.3	2.3	-1.1										
Netherlands	7.6	1.7	2.8	-5.5	6.3	-7.1									
Canada	-0.9	4.9	3.6	4.4	4.8	7.2	-0.2								
Japan	5.0	9.2	7.7	8.5	8.8	11.4	4.8	-0.7							
Spain	4.1	4.5	-0.2	3.8	3.7	6.6	3.8	8.0	-0.9						
Hong Kong	2.9	6.8	5.3	6.0	6.3	9.0	2.8	3.9	5.6	-52.8					
India	2.5	6.0	4.4	5.2	5.3	8.1	2.3	5.0	4.7	1.9	-0.7				
South Korea	6.4	10.5	9.0	9.8	10.1	12.8	6.2	3.3	9.3	4.4	6.1	-4.3			
Singapore	0.5	4.3	2.8	3.5	3.8	6.4	0.4	2.6	3.0	-1.1	-0.8	3.7	-61.0		
Russia	1.0	4.5	3.0	3.7	4.1	6.5	0.7	3.0	3.4	1.0	0.7	4.0	-0.8	-0.6	
China	1.6	5.3	3.8	4.6	4.8	7.4	1.4	2.8	4.1	-1.1	0.3	3.1	-1.4	-1.1	-0.5
Country percent change	**2.4**	**4.2**	**2.2**	**1.8**	**4.2**	**2.3**	**0.5**	**5.2**	**3.6**	**1.1**	**3.4**	**5.9**	**0.1**	**3.0**	**2.1**
World percent Change	**3.01**														

Table 2.6 Eurozone Trade Effect

Papers	Estimated trade effect of EMU	Sample	Years
MSO(2003)	5%-10%	22 developed countries	1992-2002
Berger and Niche(2005)	15%-40%, insignificant	22 developed countries	1948-2003
Flam and Nordstram(2006)	7.5% - 15%	22 developed countries	1989-2002
Nardis and Vicarelli(2003)	9%	30 countries	1980-2000
Frankel(2010)	10% - 15%	22 developed countries	1992-2006
Frankel(2010)	200%	Whole world	1945-2006
Bun & Klaassen(2007)	2% insignificant	20 developed countries	1992-2002
Baldwin & Taglioni(2007)	-10%	22 developed countries	1992-2002
Baldwin & Taglioni(2007)	-2% insignificant	22 developed countries	1980-2004
Baldwin & Taglioni(2007)	10% (traditonal)	22 developed countries	1992-2002

Table 2.7 Eurozone Effect on Trade Years 1992-2012

	1	2	3	4	5	6	7	8
Alpha Coefficients	baseline	interaction	alternative dist	with lag	GE base	GE inter	Exp/imp base	Exp/imp inter
α_g		-0.25	-0.4	-0.35		-0.1		-0.1
α_x		-0.6	-0.4	-0.6		-0.7		-0.7
Beta Coefficients								
$g_t^{\alpha_g} x_{ij}^{\alpha_x}$		**-0.270*****	**-0.531*****	**-0.220*****		**-0.251*****		**-0.248*****
		(-6.637)	**(-4.256)**	**(-4.576)**		**(-3.930)**		**(-3.826)**
$g_{t-1}^{\alpha_g} x_{ij}^{\alpha_x}$				**-0.0671***		**0.0189**		**0.0158**
				(-1.703)		**(0.392)**		**(0.336)**
GDP 1	0.218	0.429*	0.424*	0.434*				
	(0.910)	(1.790)	(1.762)	(1.810)				
GDP 2	0.543**	0.755***	0.749***	0.760***				
	(2.490)	(3.413)	(3.356)	(3.433)				
GDP/Capita 1	0.464*	0.208	0.208	0.201				
	(1.701)	(0.763)	(0.761)	(0.734)				
GDP/Capita 2	0.0990	-0.157	-0.157	-0.165				
	(0.388)	(-0.607)	(-0.601)	(-0.635)				
EMU	**0.0941*****	**0.0660****	**0.0730****	**0.0679****	**0.103*****	**0.0703***	**0.103*****	**0.0698***
	(3.187)	**(2.359)**	**(2.575)**	**(2.394)**	**(2.739)**	**(1.864)**	**(2.784)**	**(1.892)**
FTA	0.0186	0.00457	0.00428	0.00604	0.302***	0.278***	0.301***	0.276***
	(0.568)	(0.142)	(0.133)	(0.187)	(5.983)	(5.526)	(6.120)	(5.638)
RER 1	-0.343***	-0.281**	-0.272**	-0.280**				
	(-2.683)	(-2.245)	(-2.179)	(-2.232)				
RER 2	-0.177	-0.115	-0.105	-0.114				
	(-1.479)	(-0.974)	(-0.892)	(-0.963)				
Observations	11,142	11,142	11,142	11,142	63,206	63,206	63,206	63,206

Year dummies and country-pair fixed effects included in all, specifications: 1-4 indust. countries only, 5-8 all 60 selected countries from Appen B.
Cluster-robust t-statistics in parentheses , *** p<0.01, ** p<0.05, * p<0.1

Table 2.8 GE Gravity Results for Eurozone Effect on Trade
(percent reduction in trade calculated from the hypothetical removal of the eurozone for year 2012)

	Austria	Belgium	France	Germany	Italy	Luxembourg	Netherlands	Finland	Greece	Ireland	Portugal	Spain	Slovak ia
Austria	-1.91												
Belgium	3.38	-5.43											
France	5.52	3.91	-0.81										
Germany	5.41	3.79	5.92	-1.05									
Italy	5.59	3.97	6.10	5.99	-0.67								
Luxembourg	4.87	3.24	5.38	5.26	5.45	-2.22							
Netherlands	4.21	2.57	4.73	4.61	4.79	4.06	-3.63						
Finland	5.60	3.98	6.11	5.99	6.17	5.46	4.80	-0.65					
Greece	5.71	4.10	6.22	6.11	6.29	5.57	4.92	6.29	-0.41				
Ireland	5.37	3.76	5.89	5.77	5.95	5.23	4.58	5.96	6.08	-1.13			
Portugal	5.27	3.65	5.78	5.67	5.85	5.13	4.47	5.85	5.97	5.63	-1.35		
Spain	5.54	3.93	6.05	5.94	6.12	5.40	4.75	6.12	6.24	5.91	5.80	-0.77	
Slovakia	4.24	2.60	4.76	4.64	4.83	4.10	3.43	4.83	4.94	4.61	4.50	4.78	-3.56
Percent trade change for each country	**5.23**	**3.46**	**5.42**	**5.21**	**5.70**	**4.58**	**4.06**	**5.50**	**5.87**	**5.03**	**5.53**	**5.76**	**4.63**
Percent change in trade from all EMU countries	**4.95**												

Figure 2.1 Average Annual Oil Price

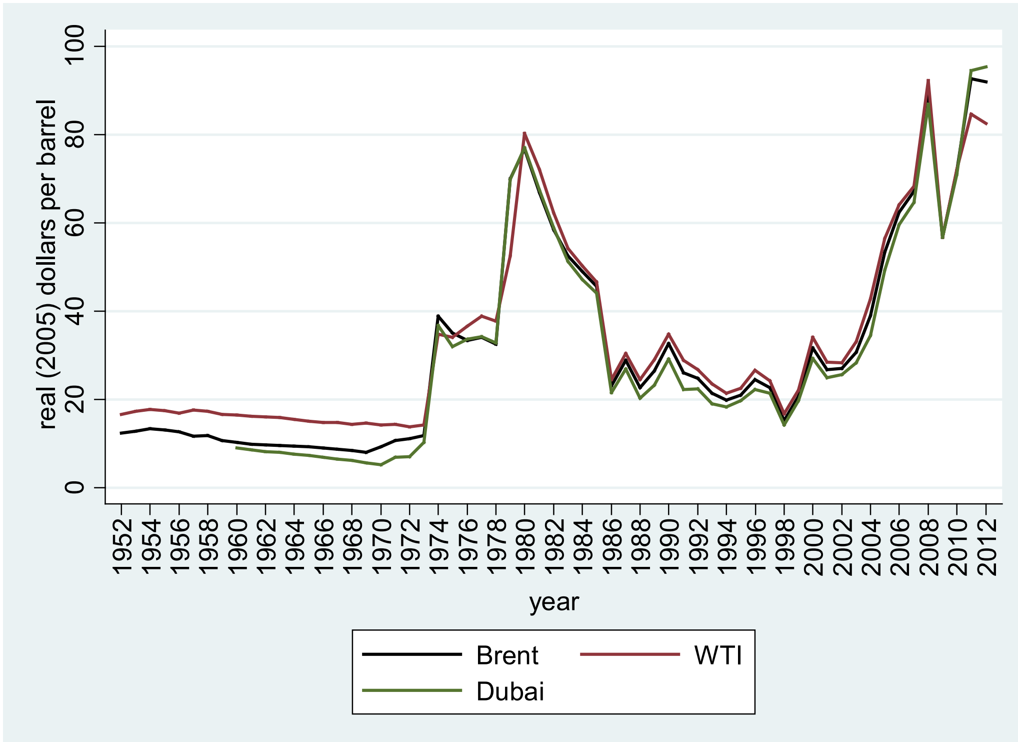


Figure 2.2 Ad Valorem Shipping Costs

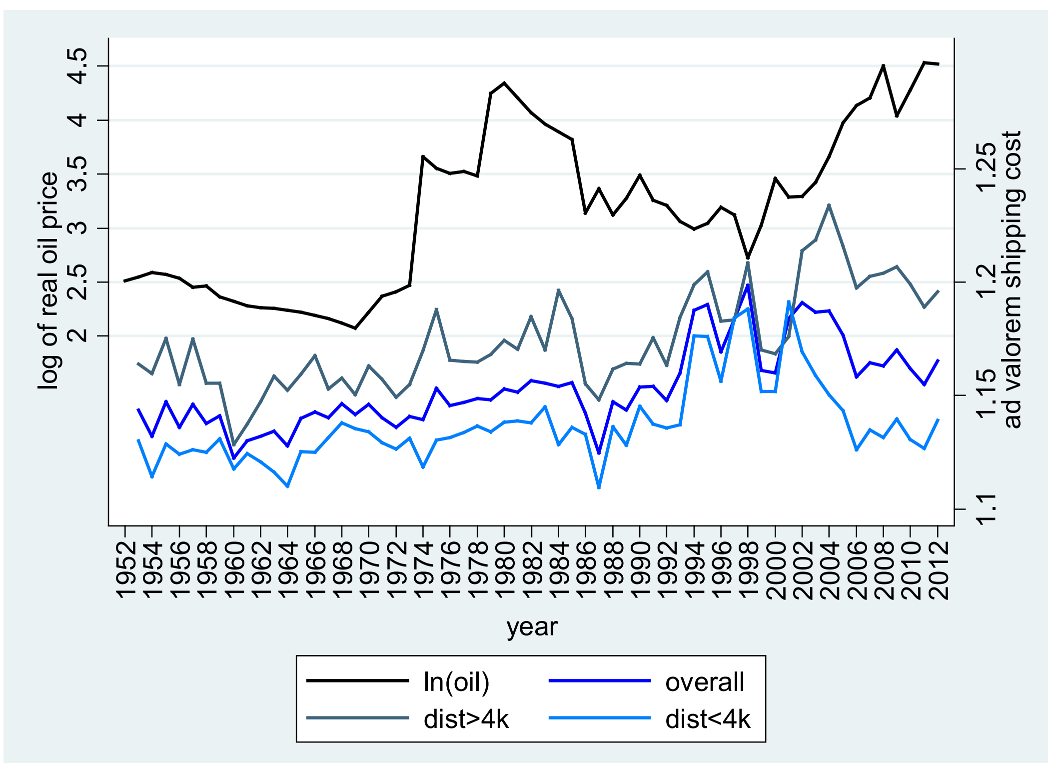
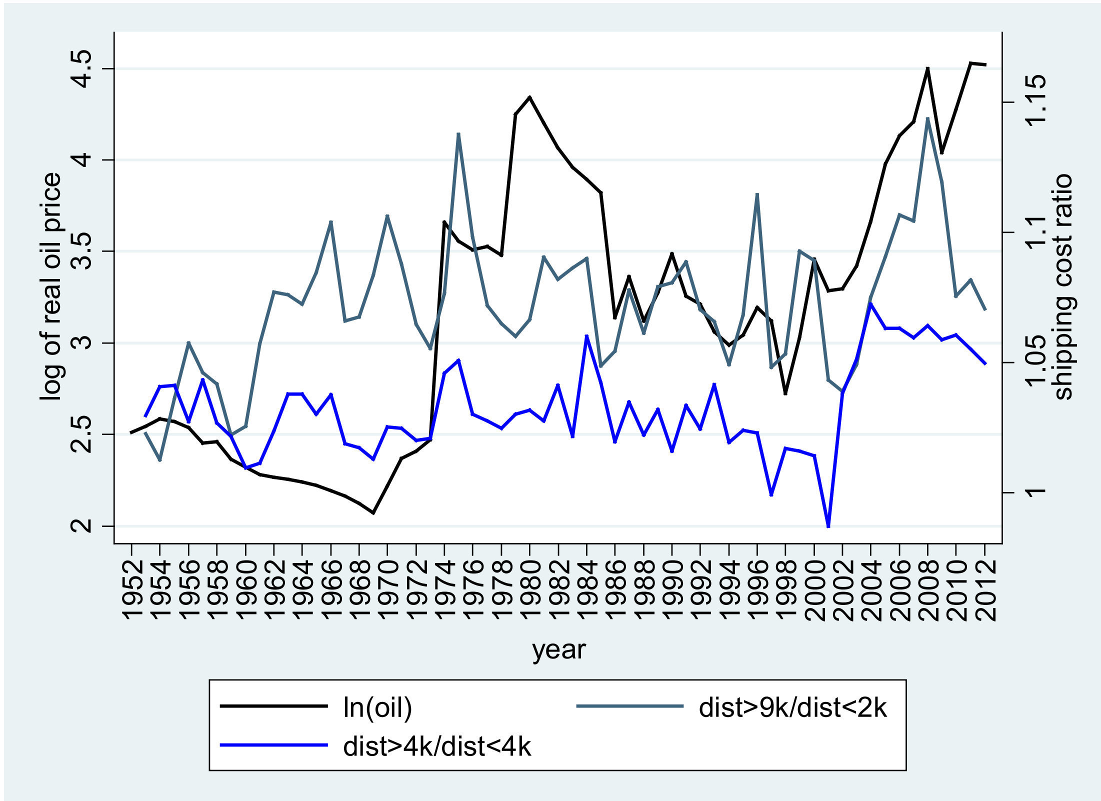


Figure 2.3 Shipping Cost Ratios



3 Test for Optimum Currency Area and Monetary Independence in the Eurozone

3.1 Introduction

The recent financial crisis had damaging effects on the eurozone, but perhaps the hardest hit were the periphery countries - Spain, Portugal, Ireland, and Greece. In the past few years Ireland and Portugal experienced unemployment rates around 15% while Greece and Spain had unemployment rates over 25%. In contrast the German unemployment rate never reached 8% and was below 5% at the end of 2014. These are significant differences given that the countries are highly integrated and share a common currency. The conventional explanation is that historically the periphery had higher interest rates and more stringent financial conditions than the other euro members. Once in the eurozone they were more easily able to raise funds from the other euro members due to the low interest rates and the elimination of the exchange rate risk that the euro provided. This led to the accumulation of mostly public debt for Greece and Portugal, and mostly private debt (a housing bubble) for Spain and Ireland. With the start of the financial crisis in 2008 the capital inflows to these countries came to a halt, thus causing spending and investment to slow, which in turn led to the massive economic downturn and the high unemployment that we see today. This dynamic is summarized in the countries' interest rates prior to the creation of the euro area, and their current accounts after joining the currency union. Figure 3.1 shows the short term interbank rates prior to the creation of the euro. As can be seen the periphery countries generally had interest rates above 5%, while Germany (and eventually the eurozone) had not exceeded this number. Figure 3.2 shows the current accounts after 1999. The figure indicates that for each year the periphery were net borrowers, while Germany became a net creditor. It appears that the borrowing intensified between 2003 and 2008. Further, as the capital inflows slowed after 2008, the current accounts began to rise. For a more detailed summary of the eurozone crisis see Lane (2012), Fernandez-Villaverde et al. (2013), and Shambaugh (2012).

As mentioned in the above papers, it appears that the monetary policy of the euro area was not ideal for the periphery as it kept interest rates too low. On the other hand, considering the current economic conditions, it appears to have been much more suitable for Germany and the other euro members. The goal of this paper is to more formally investigate these differences in desired monetary policy by using tests for monetary independence. In essence, these tests compare the euro monetary policy to the desired monetary policy of each member country. More specifically, in the conduct of monetary policy the ECB influences the short term interbank interest rate – the Euribor. This is considered a conventional monetary policy instrument and is the same percentage across all member countries. On the other hand, a country specific desired monetary policy may be indicated by a desired interest rate constructed from a Taylor rule. Therefore, to test the above hypothesis, we compare this desired interest rate for all member countries to the Euribor. If they closely match, then it can be said that the ECB policy resembles the desired policy of the member country; we expect this to be the case for Germany. On the other end, if there are significant differences, then the ECB policy does not correspond to the desired policy of the particular country; we expect this to be the case for the periphery. This analysis is in the spirit of Taylor (2007), and Khan (2010) who show that in the case of the U.S., the federal funds rate was below its desired (Taylor rule) interest rate prior to the crisis, and this, they argue, contributed to easy borrowing conditions which eventually led to the housing boom.

The above interest rate comparison test can be considered a test for monetary independence within a currency union. When countries join a currency union, it is said that they officially give up their monetary independence.[30] In the case of the eurozone, the duties have transferred to the common ECB. However, some countries might have desired interest rates that closely resemble those of the euro. For these, it is as if they have not really given up their own monetary policy as their desired interest rates are

[30] Monetary independence means that the central bank is able to conduct its own monetary policy and therefore has control over the interest rate (or exchange rate) of its currency. In accordance with the trilemma, the central bank cannot influence both the interest rate and exchange rate independently unless it imposes capital controls.

being realized. In this case, they can be considered monetarily independent as they have retained their desired policy after joining the currency union. On the other hand, if their desired interest rates are significantly different from the euro rate, then these countries wish to have a different monetary policy, but they have to comply with the policy of the ECB. For these, the Euro comes at a significant cost and they can be considered monetarily dependent. In this paper we are not trying to make a causal argument as to whether particular countries influence the decisions of the ECB but only compare the movements across interest rates.

The above tests can also be considered for optimum currency area tests different from the standard tests used in Mundell's (1961) criteria of high labor mobility, symmetry of economic shocks, and flexibility of prices. Mundell's optimum currency area criteria assess whether a common monetary policy suits the members of a currency union. Deviations from the criteria represent the overall cost of giving up their own monetary policy and (as Mundell states) thus not being able to use the exchange rate as an adjustment mechanism. Our monetary independence tests are also able to capture the essence of the criteria. Instead of using tests based on the criteria, we compare the monetary policy recommendations themselves directly; these are based on the desired interest rates. Countries that are considered monetarily independent have desired policies similar to those of the common central bank and therefore can be seen as forming an optimum currency area. On the other hand, countries that are considered monetarily dependent have significantly different desired policies. In this case the sharing of the common currency has come at a significant cost, and thus they do not form an optimum currency area.

To summarize, there are two parts to the methodology. First, the desired interest rates are obtained using the renowned Taylor rule. In the literature, this interest rate has often been referred to as the as the optimum rate, the desired rate, and a benchmark or a guidepost for monetary policy. In the second part, the interest rate comparison tests follow key papers from the monetary independence literature.

Applying the above methodology, this paper is able to answer a few important questions. First; could the current struggles of the periphery countries have been foreseen prior to the crisis? By answering this question we are able to test the idea that the monetary policy of the ECB was too loose for periphery countries prior to the recession. Second; is the eurozone an optimum currency area – if not, which countries belong and which ones do not? Third; does belonging in the eurozone change the economic structure of countries so that they are a better fit for the common policies? Fourth; did countries make the necessary adjustments after the crisis so that they are a better fit for the currency union?

The rest of this paper is organized as follows: Section 3.2 discusses the construct of the desired interest rates. Section 3.3 discusses the methodology of the monetary independence tests used in this paper. Section 3.4 reports the results. Section 3.5 concludes. Figures and tables are at the end.

3.2 The Desired Interest Rate

This section constructs the desired interest rates for all original members of the eurozone from 1999 - 2014. Eventually, these are the interest rates that will be compared to the euro rate in the monetary independence tests. First discussed is the Taylor rule literature that these rates are based on, then the methodology in their construction and the data, and finally their computations and graphical results.

3.2.1 The Taylor Rule

To construct the desired (Taylor rule) interest rates, this paper closely follows the methodology first discussed by Taylor (1993) and later augmented by Clarida, Gali, and Gertler (CGG) (1998, 2000). The rule is an interest rate reaction function popularized by Taylor (1993):

$$i_t = \alpha_0 + \alpha_1 \pi_t + \alpha_2 y_t + e_t$$

In the rule, the central bank adjusts the actual short run interest rate (i_t) in accordance to inflation (π_t) and the output gap (y_t)[31]. This rule helps the central bank to combat inflation and reach the potential output level for economy. The alpha coefficients are policy function parameters chosen by the central bank. It is assumed that $\alpha_1 > 1$ and $\alpha_2 > 0$. By the rule, if there is inflationary pressure, then the central bank is to increase the interest rate (through contractionary monetary policy) by more than the inflation increase ($\alpha_1 > 1$); this is known as the Taylor Principle. When there is a positive output gap, the central bank should also increase the interest rate ($\alpha_2 > 0$). These interest rate increases ultimately increase the real interest rate which will combat inflation and help smooth the business cycle. Taylor (1993) shows that the fitted interest rate[32] with set parameters ($\alpha_0,\ \alpha_1,\ \alpha_2 = 1\ , 1.5,\ 0.5$) describes the federal funds rate well from 1987-1992, although the rule was never actually considered by the Federal Open Market Committee (FOMC). Further, as pointed out by Taylor (1999), in the periods when the federal funds rate did not follow the Taylor rule, there were extended periods of inflation or capacity underutilization. Although the Taylor rule has not been mechanically followed in practice (having been only under some consideration at different central banks) [33], it describes the behavior of different central banks well. In particular, see Gerlach and Schnabel (2000) who study the pre-euro area of the 1990s and conclude that the euro countries do follow a Taylor rule. Also, Hayo and Hofmann (2006) compare the ECB to the Bundesbank and conclude that both follow the Taylor rule but with slightly different output gap responses. The notable paper, Clarida, Gali and Gertler (1998) looks at major world central banks and concludes that they follow a Taylor rule. This is not surprising; in accordance with theory, Woodford (2001) claims that if the goals are to limit inflation and stabilize output, then following a Taylor rule that is consistent with the Taylor principle is indeed optimum.

[31] The output gap is defined by the difference between actual GDP and potential (long run) GDP. In times of economic booms the actual is above the potential, and in times of recessions, the actual is lower than the potential. Normally an HP filter is used for the construction of the output gap.
[32] Also known as the Taylor rule interest rate; in this paper it will be referred to as the desired interest rate.
[33] See Asso et al. (2010) for the Taylor rule's role in practice.

In papers by Clarida, Gali and Gertler - CGG (1998, 2000), the original Taylor rule is first augmented to include expectations, and then to include interest rate smoothing in its estimation. CGG first consider a forward-looking Taylor policy rule where the desired interest rate is given by a function of expected future economic conditions – inflation and the output gap:

$$(1) \qquad i_t^* = \alpha_0 + \alpha_1 E_t[\pi_{t+k}] + \alpha_2 E_t[y_{t+k}]$$

Where: i_t^* is the desired interest rate (or the target interest rate as in CGG). $E_t[\pi_{t+k}]$ is expected future inflation for period $t+k$ and $E_t[y_{t+k}]$ is the expected future output gap for period $t+k$. The alpha parameters are assumed to be unknown. The above equation produces the desired interest rate, however the behavior of the real world actual interest rate for many central banks is smoother.[34] In particular, the model for the actual rate follows a weighted average of the lagged actual rate and the contemporaneous desired rate:

$$i_t = pi_{t-1} + (1-p)i_t^* + e_t$$

$$(2) \qquad = pi_{t-1} + (1-p)\alpha_0 + (1-p)\alpha_1 E_t[\pi_{t+k}] + (1-p)\alpha_2 E_t[y_{t+k}] + e_t$$

The way to obtain the desired interest rate is to estimate the above equation using generalized methods of moments (GMM) estimation and obtain the structural alpha parameters. Then one can manually compute the desired rate in eq. (1) using these parameters and realized values for the inflation and the output gap.

3.2.2 Methodology

The methodology in obtaining the country specific desired interest rates follows Clarida Gali and Gertler (1998, 2000). From eq. (1) the desired interest rate requires the alpha parameters and data on country specific output gap and inflation. To obtain the

[34] As brought up in Goodfriend (1991), the federal funds rate shows high persistence and there are only fine adjustments (interest rate smoothing). CGG (2000 p. 152) argue two reasons for this: 1) When there are large adjustments, there is fear in the disruption of financial markets and uncertainty about their effects on the economy. 2) It is also perhaps not possible for the central bank to instantly make large adjustments.

alpha parameters, the estimation of eq. (2) is required. Additionally, the data is only available on country specific inflation and output, and euro area specific inflation, output, and the actual interest rate (the Euribor). The lack of country specific actual interest rates after 1999 prohibits the estimation of the country specific reaction function. Therefore, two methods are considered in obtaining the parameters. In method 1, the parameters are obtained from estimating eq. (2) using data for the whole euro area and then imposing the estimated parameters on all member countries. In method 2, it is possible to obtain country specific parameters using data prior to the creation of the euro area. In particular eq. (2) is estimated using country specific data on inflation, output, and the actual interest rate from 1985-1999. In this method the parameters are estimated before the creation of the euro but used after its creation. This assumes that the monetary policy reaction function is going to be the same in the euro area as it was a decade earlier.

This paper considers method 1 to be the preferred method. There are a few reasons why, but first let's start with the facts. It is worth to note that we are interested in comparing the desired country interest rate to the interest rate of eurozone, but ultimately we would want to compare all the country relationships against each other; otherwise there would not really be a baseline. Second, the computed desired interest rates in eq. 1 depend on two parts: the reaction function parameters (given by $\alpha_1, \alpha_2, and\ \alpha_3$) and the economic conditions (given by the output gap and inflation rate). In method 1 we are effectively fixing the reaction policies to be the same across countries, and in method 2 we allow for differences. Although the reaction policies might be the same across countries with method 1, the economic conditions will differ, thus producing different desired interest rates and thus a different desired monetary policy. The reasons for using method 1 and not method 2 are:

1: The Taylor rule reaction function is optimum on theoretical grounds. If the ECB indeed follows the Taylor rule[35] then it has goals to limit inflation and stabilize output.

[35] As shown in the results, this does appear to be the case.

There is no reason why these will not be the same goals for the other members. For smaller countries, the reaction functions may change with the governing body of central banks, and having significant differences from the Taylor rule might not truly reflect what is best for the country. Having a Taylor rule reaction function of a large currency area is therefore reasonable.

2: Having the same alpha coefficients across countries limits the basis of comparison to actual economic conditions. We thus know that the results are not simply due to differences in reaction function policy. It is a stronger argument to say that even if the monetary policy reaction functions were the same across countries, the countries would still differ significantly in their desired monetary policy due to differences in their economic conditions.

3: Method 2 assumes that the reaction function from the late 1980s and 1990s is going to be the same as in the 2000s and 2010s for all countries of the eurozone. This is not very reasonable, as the science of monetary policy has progressed much more since then and countries have adjusted to following more strict monetary policies.

4: The results from method 2 are not very robust. Should prior country data be used starting from 1985, 1990, or 1995? Different countries had different experiences during these years, governments and policies also change depending on the years. It is therefore not surprising that using different years also produces different parameter estimates depending on the country. Further many do not fit the model of CGG. Some do not follow the Taylor principle, a couple have negative inflation or output gap parameters, and a few also have eq. (2) with an estimated smoothing parameter $p > 1$.

Based on these arguments we decide to adopt method 1. With this method all the eurozone members will have the same reasonable reaction function, and we will be able to clearly see the differences in the desired rates based on their economic conditions. As a robustness check, traditional coefficients (from Taylor, 1993) for the constant, inflation, and output gap are imposed, and the results remain similar.

3.2.3 Data

Following CGG this study will rely on monthly data in computing the desired interest rate. The IMF - International financial statistics (IFS) provides monthly data on CPI inflation and industrial production for the eurozone as a whole and all its members individually from January 1999 through December 2014. Seasonally adjusted unemployment rates are gathered from the OECD for the same countries and dates. The Figures 3.3-3.9 show these for the eurozone members and the eurozone as a whole. For estimating eq. (2), the actual interest rate is the three month Euribor rate also taken from the IFS. As in CGG the CPI inflation, defined as the annual change in the CPI, will be used as the inflation variable. As for the output gap, monthly data on GDP is not available; CGG instead use the cyclical component of detrended industrial production. However, as can be seen from Figure 3.3 there is not a large difference in the industrial production behavior between the countries. When the industrial production gap is considered the differences across countries are very small. Then, perhaps this is not a good representation of the economic conditions affecting the countries. As seen from the unemployment rates in Figure 3.4, Spain was clearly more affected by the crisis. As mentioned in Longbrake (2008 p.46) and McCulloh (2007), the unemployment gap can be used as an alternative.[36] The unemployment gap is the cyclical component of the H-P filter[37] on seasonally adjusted monthly unemployment rates. We choose to employ unemployment as the output variable for fourth reasons. Firstly, industry is a relatively small segment of the economy in many European economies (only 20-30 percent).[38] Secondly, it is more variable and more dissimilar across countries (See Figure 3.4). Thirdly, it provides a better fit in the estimation of eq. (2). Since unemployment is inversely related to output, the sign on its coefficient (α_2) is expected to be negative.

[36] Ball and Tchaidze (2002) use a similar unemployment measure.
[37] As recommended by Ravn and Uhlig (2002) for monthly data the smoothing parameter used is 129600.
[38] See the CIA World Factbook - https://www.cia.gov/library/publications/the-world-factbook/fields/2012.html

3.2.4 Estimation Results

Equation (2) is estimated using eurozone specific data. It is assumed that future inflation and unemployment is not observed at the time the interest rate is set; therefore their future realizations are instrumented using GMM IV. The instruments used are past lags of the variables in the model for months 1-6, 9, and 12 (as also used in CGG, 1998). The recent lags are more frequent as it is assumed that they are better predictors of the future variables. Also following CGG, the real effective exchange rate is included as a variable to control for foreign monetary shocks. Data for this variable is also taken from the IFS and is given as foreign currencies per unit of a home currency. Theoretically the central bank should lower interest rates when there is currency appreciation pressure (to keep the currency from appreciating further) and vice versa if there is currency depreciation pressure. However, as pointed out in Taylor (2001), the effects on the real exchange rate are usually taken into account in the expected future inflation and unemployment gap that are already in the model. Consistent with this theory, there is little difference in the results if the real exchange rate is not included.

It is also important to choose the lead (k) in the variables of eq. (2). Different values for the leads are considered. Table 3.1 shows the results for leads 3, 6, and 9. All produce similarly goods fits and the computed structural parameters of eq. 1 are shown at the bottom. As we can see the structural parameters follow the Taylor rule with computed coefficients of $\alpha_1 > 1$ and $\alpha_2 < 0$. The third lead is chosen in the computation; first it has the correct sign on the real exchange rate, and further the instruments are stronger in explaining the nearer future.[39] As a final point, the monetary independence results remain similar no matter what lead is used.

3.2.5 Figures

Figures 3.10-3.12 plot the computed desired interest rates from all original members of the eurozone, as well as the eurozone as a whole given in violet, and the actual eurozone rate given in black. As we can see the desired interest rates are much

[39] When the model is run without instruments (only OLS) the 3rd lead produces the closest results to the GMM results.

more volatile than the actual eurozone rate. This is because the eurozone tends to substantially smooth interest rates; this can be seen from the estimated parameter of the lagged interest rate of .983 in Table 3.1. The interpretation of these results is discussed in the results in section 3.4.

3.3 Monetary Independence and Optimum Currency Area Tests

As stated in the introduction we are interested in comparing the desired interest rates in order to determine whether certain countries may be considered monetarily independent thus forming an optimum currency area. This section first introduces a brief literature review from the monetary independence and optimum currency area literatures. A few different monetary independence tests will be considered. The baseline test will simply be a summary of the graphical results showing the distance between the euro rate and the desired country rate. This baseline test does not provide enough detail as to the differences in movement between the rates. Therefore, the movement is analyzed further below by traditional monetary independence regressions; versions of these are also used for short run results. Finally to validate the results a vector error correction model is run.

3.3.1 Monetary Independence Literature

In order compare the constructed desired rates and the eurozone rate, traditional monetary independence tests will be used. The methodologies in this paper will closely follow the key papers of Frankel et al. (2004) and Shambaugh (2004).[40] These authors test to see if countries with a flexible exchange rate regime are more monetarily independent than those with a fixed exchange rate regime. To do this, the authors use regressions to compare the movement of a base country interest rate (mainly the U.S.) to the interest rate of a smaller home country. The logic in doing this stems from interest rate parity. Under a credible fixed exchange rate regime, the exchange rates are fixed and therefore the interest rates should be equal. However, as pointed out in Shambaugh (2004), one reason they might not be equal is due to the differences in risk

[40] For similar studies also see Bluedorn and Bowdler (2010) and Obstfeld, Shambaugh, and Taylor (2005).

premium between the two countries. However, If these differences remain constant over time we should still see close movement between the two interest rates. On the other hand, if the small country has a floating exchange rate regime it is expected to have control over its own interest rate, therefore, there should not be a significant correlation between its interest rate and the base country interest rate.

The two country version of the baseline regression in Frankel et al. (2004) is:

$$(3) \qquad i_t^{Country} = \beta_0 + \beta_1 i_t^{Base} + e_t$$

Where: $i_t^{Country}$ is the small country interest rate and i_t^{Base} is the base country interest rate in period t. It is concluded that if there is a good fit and the estimate of β_1 is close to one, then the small country interest rate moves one for one with the base country interest rate, and therefore the small country is said to be monetarily dependent. On the other hand, if the estimate is not significant and closer to zero, it is assumed that the country is monetarily independent. Eq. (3) shows the long run relationships between the interest rates. Similarly, a first differenced regression will test for a short run relationship. For this paper, the coefficient interpretation is actually reversed; more on this later in the section.

3.3.2 Optimum Currency Area

The monetary independence tests may also be considered optimum currency area tests. Countries are said to form an optimum currency area if there are high benefits and low costs to joining. A large benefit is the increased trade due to the elimination of exchange rate risk, the reduction of transaction costs, and the greater price transparency that a common currency provides. A large cost is the forgoing of individual monetary policy in order to pursue a common monetary policy. Mundell (1961) provides criteria to assess whether a common monetary policy would suit all members; this includes high labor mobility, symmetry of economic shocks, and flexibility of prices. Many papers test to see if there are symmetry of shocks/business cycles across the member countries by using simple correlations. For example see Bayoumi and Eichengreen (1994), and Kim and Chow (2003). The last section compares our results to those of different papers. These papers assume that if there is close symmetry then a common monetary policy would be suitable, and if there is asymmetry, then they would require different monetary responses, and therefore a common monetary policy will not be suitable. This literature is reasonable to assume that differences in shocks would require different policies but does not examine the magnitude of the differences. In other words these traditional tests never actually state what the recommended policy responses would be. The important questions are: What are the monetary policy recommendations based on the shocks, and how do these policy recommendations differ across countries? Our method is able to answer these questions by comparing the policy recommendations themselves. Instead of computing different kinds of shocks we take a short cut and observe their effects through changes in the economic conditions (unemployment gap and inflation) which in turn produce changes in the desired interest rate; this is the monetary policy recommendation. If a country has a comparable desired interest rate to the euro rate then the ECB policy is suitable for the country and it can be considered to form an optimum currency area. On the other hand, if they are not comparable, then the ECB policy is not suitable for the country, and it is therefore not considered to form an optimum currency area.

3.3.3 Baseline Test

The first test is a statistic of the distances between the interest rates. Consider a simple average absolute difference (AAD) :

$$(4) \quad Average\ Absolute\ Difference\ (AAD) = \sum_t \left| i_t^{euro} - i_t^{country} \right| / T$$

Where, i_t^{euro} and $i_t^{country}$ are the Euribor and a country specific desired interest rate in month t. This statistic represents the average distance between the two rates as shown for each country in the Figures 3.10 through 3.12. Countries with relatively low AAD have desired interest rates that closely match the euro rate; while countries with high AAD have desired rates that are significantly different from the euro rate. This statistic could be used to test the hypothesis that the euro rate was too low for the periphery countries before the recent recession, and this led to the accumulation of debt and economic overheating.

3.3.4 Monetary Independence Regressions

The AAD statistic above compares how close the interest rates are to each other; however, this is only a broad monetary independence test. In the spirit of traditional monetary independence tests, there is an emphasis on comparing the movements of the interest rates instead. Although the interest rates may be close, their movements may not coincide and this might be important. For example, suppose there is an economic shock that affects the eurozone and all its members and thus requires a monetary response. The monetary response by the eurozone (of lowering or raising the interest rate) will thus benefit the countries that have recommended responses that are also similar. In this case countries that have desired rates which move with the euro rate will benefit the most.

To test for similarities in movement we consider a traditional monetary independence regression and regress the euro rate on the desired country interest rate for each member:

$$(5) \qquad i_t^{Euro} = \beta_0 + \beta_1 i_t^{Country} + e_t$$

Here if the estimate of β_1 is close to one and there is a reasonably good fit, then it can be said that the euro rate moves one to one with the desired country rate, and therefore, the country is considered monetarily independent because it is as if the euro rate is following its desired interest rate. On the other hand if β_1 is different from one and there is a poor regression fit, then the member is considered monetarily dependent as it is bound to follow the policies of the euro instead of its own desired policies. It is important to note that when using the above regression we are not trying to make a causal argument as to whether the desired interest rate of a particular country causes the euro rate; we are simply using the regression to compare movement.

Running the above model leads to poor regression results for all members. Perhaps this is due to the substantial interest rate smoothing and the zero lower bound that are present in the actual euro rate. As shown in Figures 3.10 through 3.12 and Table 3.1, even the euro itself (in black) does not closely follow its desired rate (in violet) because of these factors. So a regression with the actual euro rate may not be fully appropriate. Instead of using the actual euro rate, perhaps a better (and more apples-to-apples) comparison is with the movement of the desired euro rate instead. To make this comparison more valid, it is reasonable to assume that given monetary autonomy, each country will also smooth its desired interest rate and also be unable to cross the zero lower bound. Then, a country with a desired rate similar to the desired rate of the eurozone will have an actual rate (given monetary autonomy) similar to the actual rate of eurozone. In this case, the actual ECB policy will be in line with the desired policy of the country although their interest rates (the actual euro and the desired country rate) might substantially differ. Given these reasons, this paper uses the desired euro interest rate instead of the actual euro rate in eq. (5). A basic augmented dicky – fuller test also reveals that the desired rates time series are stationary for all countries either at the 1% or the 5% levels, but causality is not argued here.

3.3.5 Long, Medium, and Short Runs and a VECM

Equation (5) looks at the behavior of the interest rates in the long run. Large differences in the movement here might indicate long term consequences. As an example, consider the Spanish desired rate in Figure 3.10. As we can see there was a larger increase in the desired rate of Spain relative to the euro from 2004-2008, and a larger drop after 2008. Therefore, when running the regression we expect to see a beta coefficient less than 1. One might interpret the increase as economic overheating generated from a housing bubble and the accumulation of debt, and the decrease as the harder crash that occurred during the crisis. The figures also show that the euro policy was not accommodative as the euro rate increased at a much slower pace.

As monetary policy is assumed to only influence the short run, it might be argued that there are no long term consequences from differences in long run movements. A further weakness is that the regression does not provide information on the exact timing of the interest rate movements. Ultimately, given shocks, it would be best if the euro response coincides with the desired response of the particular country. To test this eq. 5 is converted into first differences:

$$\Delta i_t = i_t - i_{t-p}$$

In standard first differences p is 1; as the data is monthly, this can be seen as the monthly first difference. We also consider p being 3, 6, and 12, to represent quarterly, semiannual, and annual first differences. These lengths represent similarities in movements across the short run and up to the medium and longer runs. Similarities in monthly first differences represent similarities in the effects of smaller shocks and parts of larger shocks. Maybe this horizon is too short to be of real concern and it is perhaps more important that policies coincide for longer horizons. Similarities in quarterly differences can represent the similarities in the accumulative effects of smaller shocks, or the effects of larger shocks such as the recent financial crisis or a large increase in the oil price. Therefore it is important for desired policies to coincide for this longer run so as to better stabilize the economy and avoid further deterioration during larger shocks.

The regressions above see if the movements of the desired country rates coincide with those of the euro. To make sure the results are not a coincidence a vector error correction model (VECM) between the euro rate and each country rate is estimated. Besides being able to take into account the short and long run effects, the VECM is able to offer a causal argument by looking at influences from past lags. In particular, as the desired interest rates are based on economic conditions, the model will be able to determine whether shocks to the economic conditions of the euro influence the economic conditions of the particular country. Thus, in the spirit of traditional optimum currency area tests, this will measure how well the countries have economically integrated with the eurozone. To test, consider estimates from the VECM below:

$$(6) \qquad \Delta i_t^{Euro} = \alpha_{11} + \theta_1\left(i_{t-1}^{Euro} - \beta_0 - \beta_1 i_{t-1}^{Country}\right) + \sum_k \alpha_{12}(k)\Delta i_{t-k}^{Euro} + \sum_k \alpha_{13}(k)\Delta i_{t-k}^{Country} + e_{1t}$$

$$\Delta i_t^{Country} = \alpha_{21} + \theta_2\left(i_{t-1}^{Euro} - \beta_0 - \beta_1 i_{t-1}^{Country}\right) + \sum_k \alpha_{22}(k)\Delta i_{t-k}^{Euro} + \sum_k \alpha_{23}(k)\Delta i_{t-k}^{Country} + e_{2t}$$

Where, the variables are defined as in eq. (5) with monthly first differences indicated by the deltas. Results from the AIC criteria indicate $k = 2$ for most countries. Therefore, to be consistent across countries, two lags are used for all. These estimates along with the Choleski decomposition[41] are then able to identify shocks to the euro and shocks to the country rates. Variance decompositions are then used to indentify how these shocks influence the movements of the variables after a given period.

3.4 Results

3.4.1 Average Absolute Differences and Graphical Results

Table 3.2 shows the average absolute differences (AAD) in the interest rates throughout the entire period. The first row is the AAD between the desired country rates and the actual eurozone rate, while the second row is with the desired eurozone rate instead. The largest differences indicated by the first row appear to be in Ireland, Spain, and Greece followed by Finland, Belgium, and Portugal. The numbers in the second row are also similar.

The story of these differences is better told in Figures 3.10-3.12. In the figures, it can clearly be seen that Ireland and Spain, and to a lesser degree Portugal and Greece,

[41] The variables are ordered so that the euro shocks could influence the desired country rate contemporaneously.

had higher desired rates before the crisis. This supports the conventional story that these countries overheated prior to the crisis and crashed much harder than the other members during the crisis. It appears that the monetary policy of the euro area was not accommodative and failed to smooth the business cycle for these members. On the other hand, it can be seen that Finland and Germany, and to a lesser extent France and Austria, had lower desired interest rates prior to the crisis. The countries suffered in this prior period, but as shown in the unemployment rate figures 3.6-3.8, they had a much more mild recession afterwards. As for Belgium and the Netherlands, there were periods when both had desired rates slightly above and below the actual rate; but their economies did not overheat and they also had more mild recessions.

3.4.2 Regressions and a VECM

The results from running eq. (5) in levels are shown in Table 3.3. As we can see, the results indicate that the poorest fit is for Greece, Ireland, and Spain, and at the second tier are Portugal, Finland, and the Netherlands; on the other hand the best results are from Germany, France, Austria, Italy, and Luxembourg. These results represent the long run and tend to be consistent with the ADD results. Continuing, Table 3.4 shows the β_1 estimates along with their regression R squared[42] in the below line for all first difference regressions - the monthly, quarterly, semiannual, and annual. For the monthly first differences, we can see that only France and Germany tend to follow the euro rate because of this very short horizon. In the quarterly first difference we see a substantial improvement for Italy, Austria, Luxemburg, and the Netherlands.[43] There is also a further improvement for the semiannual and annual differences, and they more closely resemble the levels regressions. To interpret the results; relative to the other countries, only France and Germany appear to form an optimum currency area and be monetarily independent in the very short run. However, as mentioned in the previous section, the very short run only compares smaller shocks and parts of larger shocks; further due to the smoothing of the interest rate it is unlikely that the actual interest

[42] As the regression only has two variables, the square root of the R squared is their Pearson correlation coefficient.
[43] Converting the data to quarterly and then taking the first difference produces very close results.

rate will be adjusted on a monthly basis following these short run fluctuations. The longer run results more clearly show the periphery as outliers. Perhaps these results are more important than the short run as they indicate how monetary policy would respond for larger shocks and for the sum of smaller shocks.

The results of the variance decompositions from the VECM are shown in Table 3.5. The table indicates the fraction of movement in the desired country rate that is explained by euro shocks after a given month. As the desired interest rates are functions of economic conditions the results may also be interpreted for economic conditions instead. For example according to the table, it can be said that the accumulative effects of euro shocks explain 77% of the variation in Austria's economic conditions after 12 months (the long run) but only 29% of the variation after 1 month (the very short run).[44] So it appears that in the very short run Austria is not influenced by the euro, however we can see larger influences in the medium to longer runs. As for the rest of the countries, it appears that the results are consistent with the initial regression results. For example, we see that euro shocks explain the most variation in the economic conditions (desired interest rates) of France and Germany after just one month; this is consistent with the monthly first difference regressions of Table 3.4. This is not surprising as further results (not shown) indicate that euro shocks explain over 90% of the variation in the euro rate for most time horizons (in all country specific VECM estimations); as euro shocks also explain much of the interest rate variation for some members then the country and euro rate will move together as shown in the regression results. Based on the results it appears that Austria, France, and Germany are the most integrated with the euro and thus can be considered to form an optimum currency area; in the second tier are Belgium, Italy, Luxembourg, Netherlands, and Finland, while the periphery countries (expect for Spain in the short run) show the lowest euro integration.

[44] Since there are only two variables, this means that 71% of the variation in Austria's economic conditions is explained by an Austrian shock.

3.4.3 Further Questions and Robustness checks

The general results above conclude that some member countries can be considered monetarily independent and thus form an optimum currency area with the euro. To answer the questions from the introduction, regressions from eq. (5) are run for different years: 1999-April 2008 (the peak of the desired interest rate series), 1999-2003 (initial years), 2003-2008 (the housing boom), and 2010-2014 (the recovery period). Further, they are split by levels in Table 3.6, monthly differences in Table 3.7, and quarterly differences in Table 3.8. Besides answering the questions, these overall results can be used as a robustness check. As we can see, except for the long run results in Table 3.6, there are not drastic differences in the coefficient estimates across the sample splits. This indicates that the short and medium run results are not purely coincidental, and the regression model does a good job in comparing the overall economic integration with the euro.

First, could the current struggles of the periphery have been foreseen prior to the crisis? As stated in the introduction the collapse of the periphery countries had to do with the periphery's favorable borrowing conditions prior to the crisis. These imply long term consequences, so we refer to the long run 1999-2008 regressions in Table 3.6. From these we clearly see that the outliers are the Netherlands, Spain, and Ireland. It is interesting that the Netherlands is on the list but we can see from the figures and the R squared that the low coefficient has to do with the poor correlation and not because there was a substantial desired rate increase. It is also interesting to note that Greece is not on the list, and this is because it had followed the euro interest rate closely (in the long run), but looking from the graphs we see a drastic increase in its desired interest rate in the 2007-2008 period. If we instead look at the medium run results in Table 3.6, we clearly see that all the periphery countries (Ireland, Spain, Portugal, and Greece have the lowest coefficients. The answer is yes.

Second, does belonging in the eurozone change the economic structure of countries so that they are a better fit for the common policies? This question has to do with the endogeneity of optimum currency area criteria. Traditionally, this is the idea that countries become better suited for a currency union after they join the union.[45] To answer this question we compare the initial period (1999-2003) with the latter period (2003-2008) and look for improvements in both the coefficient (close to 1) and the regression fit in Tables 3.6-3.8. In the long run results of Table 3.6 we see a significant improvement for the Netherlands, Finland, Greece[46], Spain and Portugal. In Table 3.7 we look at the short run and observe that there was a significant improvement in Austria, Luxembourg, Netherlands, and Spain. In Table 3.8, the medium run, we see that there was significant improvement for Austria, Luxembourg, Netherlands, and Spain, Greece, and Portugal. In conclusion, with the exception of Ireland, we generally see improvements for countries that are a poorer fit to begin with, and little to no improvement for countries that are a good fit to begin with. This is evidence that the currency union is able to integrate the members that are less fitting, but it appears that it does not further integrate members that are already better off. Although the largest improvements were in the periphery, it appears that not enough years had passed to prevent their economic collapse.

Third and related, did countries make the necessary adjustments after the crisis so that they are a better fit for the currency union? The purpose of this question is to predict what the future holds for the eurozone. Here we are trying to see whether the members are becoming more integrated with the euro, and if after the recovery the currency union will emerge stronger thus fulfilling the desired policies of all its members. To answer the third question we compare the 2010-2014 period to the 2003-2008 period. As the members are recovering it is perhaps not a good idea to compare the long run interest rates. For example, in Table 3.6 (the long run), Ireland shows a worsening situation with the euro rate after 2010. As we can see from Figure 3.12, this is because the desired interest rate for Ireland has been increasing since 2012 while the desired euro rate has decreased. The increase for Ireland was the large drop in

[45] One of the first papers to discuss this is Frankel and Rose (1998), and the topic is reviewed in De Grauwe and Mongelli (2005).

[46] Greece only has two years of data for the initial period.

unemployment since 2012, and this does not necessarily mean that Ireland is not better integrated with the Euro. In this case the long run results can be misleading as we are dealing with recovering countries. To compare changes in integration we use the medium run results from Table 3.8 instead. Here, we see that Belgium, France, Germany, and Ireland show significant improvements in this period. Further, it might be a coincidence, but it appears that nations who improved their integration with the euro had a better recovery than those that did not. For example, if we compare the similar Latin countries of France and Italy we see that Italy had a pre-crisis unemployment rate reaching a low of 5.8 percent, and its unemployment currently (at the end of 2014) stands at 12.4 percent. On the other hand, the numbers for France are 7.1 percent before the crisis and 10.5 percent currently. Further we can compare the similar countries of Belgium and the Netherlands; the Netherlands result shows worsening integration after 2010 and it had a pre-crisis unemployment low of 3.6 percent and was close to 8 percent in 2014. On the other hand, Belgium had a pre – crisis low of 6.8 percent and its 2014 unemployment was 8.5 percent. The similar countries of Germany and Austria can also be compared; from Table 3.8 it appears that Austria did not show improvement after 2010 while Germany did show significant improvement. The unemployment numbers for Austria are 3.8 percent pre-crisis and 5.6 percent in 2014, while the numbers of Germany are 8 percent pre-crisis and 4.8 percent in 2014. We can also compare the smaller countries of Portugal, and Ireland. Portugal does not appear to have improved integration with the euro after 2010, and its unemployment numbers are 5 percent pre-crisis and 13.6 percent currently and those of Ireland being 4.5 percent before and 10.1 currently. The Overall results on whether the countries have become better integrated with the euro are mixed as many countries show stagnation or worsening.

3.4.4 Results from Other Studies

Many studies have investigated whether the eurozone forms an optimum currency area. In particular, most approaches look at the symmetry of shocks and business cycles across countries. If they are highly correlated, then it is assumed that a common monetary policy is suitable for all members and therefore they form an optimum currency area. Earlier papers placed an emphasis on the symmetry of shocks criteria. Bayoumi, and Eichengreen (1994) use the Blanchard and Quah decomposition to construct supply and demand shocks based on GDP and inflation for the euro area countries from 1960-1990. The countries with the highest shocks correlations are Germany, France, Netherlands, and Belgium while Italy, Portugal, Finland, and Ireland are the countries that fit the least with the rest; there is no data on Greece. Kim and Chow (2003) use GDP data on the euro countries and the US to construct domestic, regional, and global shocks. Variance decompositions from 1979-1998 indicate that regional (euro area) shocks explain much of the variation in output growth for France, and Austria, and explain the least amount for Ireland, Finland, Greece and Portugal.

More recent studies have looked at the symmetry of business cycles within the eurozone. In general the studies detrend country specific GDPs using a filter and then simply compare the cyclical components using correlations. Using this methodology and data from 1997-2004, Gouveia and Correia (2008) conclude that the business cycles are highly correlated except for Greece and Finland, further using rolling correlations from 1984-2004 Greece shows a large decline integration over the period. Also using a similar methodology, Gogas (2013) shows that all euro countries have high correlations with the G3 – France Germany and Italy but only Greece shows a significantly lower correlation between 1999-2010. Also using a similar methodology and data from 2000-2009, Papageorgiou et al. (2010) conclude that the least correlated members are Italy, Greece, Ireland, and Finland. Further Konstantakopoulou and Tsionas (2014), using data from 1960-2010, also conclude that Greece and Ireland have the weakest correlations with the euro.

3.5 Conclusion

This paper uses a new methodology in testing whether the countries of the eurozone are monetarily independent and therefore form an optimum currency area. The overall results based on Tables 3.3 and 3.4 show that the best candidates for an optimum currency area are Austria, France, Germany, Italy, and Luxembourg; these may also be considered monetarily independent. In the second tier are Belgium, the Netherlands, and Finland followed closely by Portugal and Spain; and finally, Ireland and Greece show the poorest results. As a robustness check the VECM is able to show that the results are not entirely a coincidence; shocks to the euro area explain much of the variation in the desired rates for the top tier countries and they give poorer results for the periphery. Further, the first differences regressions in Tables 3.7 and 3.8 are able to produce similar results for countries across different years; this can thus be used to infer economic integration. A few other conclusions can be made. First, it is clear that prior to the crisis Spain, Ireland, and (to an extent) Greece had large desired interest rate increases while the euro rate was kept relatively low. This is evidence that their economies overheated in the pre-crisis period and collapsed much harder after the crisis. Second, it can be concluded that the euro was initially able to integrate the least fitting members (except for Ireland) but this did not stop their larger crash during the crisis period. Lastly, only a few countries – France, Germany, Belgium, and Ireland show improved integration with the euro after 2010, and therefore it is uncertain whether the euro will emerge as a stronger union or continue to face problems within the near future.

Table 3.1 Taylor Rule Regressions

VARIABLES	(1) 3forward	(2) 6forward	(3) 9forward
Inflation	0.0354***	0.079***	0.0879***
	(0.0112)	(0.0157)	(0.0210)
Unemp Gap	-0.0319***	-0.0741***	-0.0952***
	(0.0118)	(0.0142)	(0.0167)
Real Exchange Rate	-0.0318	0.0178	-0.129
	(0.0971)	(0.103)	(0.101)
Lagged i-rate	0.983***	0.971***	0.963***
	(0.00605)	(0.00635)	(0.00705)
Constant	0.110	-0.175	0.497
	(0.447)	(0.473)	(0.461)
Observations	189	186	183
R-squared	0.99	0.99	0.99

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Structural Coefficients from eq. 1

Inflation	2.08	2.72	2.38
Unemp Gap	-1.88	-2.56	-2.57
Real Exchange	-1.87	0.61	-3.49
Constant	6.47	-6.03	13.43

Table 3.2 Average Absolute Differences

	Austria	Belgium	France	Germany	Italy	Luxembourg	Netherlands	Finland	Ireland	Portugal	Spain	Greece
Actual Rate	1.97	2.26	1.73	1.90	1.33	1.73	1.93	2.55	4.21	2.12	3.00	3.59
Taylor Rate	1.08	1.32	1.02	1.12	0.85	1.13	1.85	1.73	4.40	1.80	2.76	3.97

Table 3.3 Levels Regression

VARIABLES	Austria	Belgium	France	Germany	Italy	Luxembourg	Netherlands	Finland	Ireland	Portugal	Spain	Greece
desire euro rate	0.853**	0.650**	0.979**	0.986**	0.948**	0.839**	0.528**	0.559**	0.254**	0.523**	0.420**	0.189**
	(0.0396)	(0.0230)	(0.0280)	(0.0383)	(0.0426)	(0.0422)	(0.0437)	(0.0300)	(0.0131)	(0.0368)	(0.0190)	(0.0311)
Constant	0.209*	0.509**	0.797**	0.861**	-0.149	-0.192	0.771**	1.042**	1.231**	0.573**	0.524**	1.299**
	(0.123)	(0.0958)	(0.0814)	(0.101)	(0.115)	(0.134)	(0.164)	(0.115)	(0.106)	(0.144)	(0.106)	(0.158)
Observations	189	189	189	189	189	189	189	189	189	189	189	165
R-squared	0.714	0.788	0.829	0.797	0.808	0.734	0.382	0.675	0.601	0.643	0.683	0.171

Robust standard errors in parentheses

** p<0.05, * p<0.1

Table 3.4 First Difference Regressions - Beta Coefficient and R Squared

	Austria	Belgium	France	Germany	Italy	Luxembourg	Netherlands	Finland	Ireland	Portugal	Spain	Greece
Month Difference	0.457**	0.483**	0.736**	0.702**	0.577**	0.429**	0.378**	0.461**	0.310**	0.316**	0.455**	0.232**
	0.347	0.556	0.632	0.636	0.315	0.395	0.154	0.363	0.346	0.209	0.517	0.197
Quarterly Difference	0.657**	0.555**	0.870**	0.927**	0.945**	0.686**	0.572**	0.568**	0.345**	0.486**	0.464**	0.336**
	0.564	0.670	0.801	0.774	0.633	0.656	0.275	0.532	0.579	0.430	0.651	0.303
Semiannual Difference	0.754**	0.618**	0.905**	1.012**	1.060**	0.797**	0.657**	0.627**	0.355**	0.577**	0.501**	0.343**
	0.724	0.800	0.854	0.801	0.799	0.735	0.330	0.701	0.720	0.608	0.782	0.308
Annual Difference	0.822**	0.640**	0.961**	1.055**	1.055**	0.873**	0.732**	0.640**	0.353**	0.619**	0.509**	0.319**
	0.798	0.841	0.887	0.837	0.819	0.757	0.419	0.772	0.759	0.694	0.798	0.261

Coefficient estimates shown in first row

R squared shown in following row

** p<0.05, * p<0.1

Table 3.5 VECM - Variance Decompositions

month	Austria	Belgium	France	Germany	Italy	Luxembourg	Netherlands	Finland	Ireland	Portugal	Spain	Greece
|1	0.29	0.52	0.59	0.64	0.27	0.33	0.16	0.31	0.18	0.15	0.43	0.13
|2	0.42	0.51	0.66	0.72	0.44	0.55	0.23	0.40	0.23	0.21	0.42	0.17
|3	0.51	0.56	0.73	0.75	0.56	0.62	0.30	0.48	0.29	0.28	0.46	0.21
|4	0.58	0.59	0.77	0.77	0.60	0.65	0.36	0.52	0.31	0.31	0.48	0.23
|5	0.62	0.60	0.80	0.78	0.63	0.67	0.40	0.55	0.31	0.31	0.48	0.23
|6	0.66	0.61	0.82	0.78	0.64	0.66	0.44	0.57	0.31	0.31	0.47	0.23
|7	0.68	0.61	0.84	0.78	0.64	0.65	0.47	0.58	0.29	0.30	0.45	0.22
|8	0.71	0.61	0.85	0.78	0.64	0.63	0.49	0.59	0.28	0.29	0.42	0.20
|9	0.73	0.60	0.86	0.77	0.64	0.61	0.51	0.59	0.26	0.28	0.40	0.19
|10	0.74	0.60	0.87	0.77	0.63	0.58	0.53	0.59	0.24	0.26	0.37	0.18
|11	0.76	0.59	0.88	0.76	0.62	0.55	0.55	0.59	0.22	0.25	0.35	0.16
|12	0.77	0.58	0.88	0.75	0.61	0.53	0.56	0.59	0.21	0.23	0.33	0.15

Table 3.6 Sample Split Level Regressions (Long Run)

	Austria	Belgium	France	Germany	Italy	Luxembourg	Netherlands	Finland	Ireland	Portugal	Spain	Greece
1999-2003	0.663**	0.504**	0.696**	0.810**	1.040**	0.744**	0.507**	0.385**	0.365**	0.574**	0.343**	0.0668
	0.760	0.688	0.728	0.868	0.844	0.796	0.524	0.281	0.647	0.638	0.250	0.005
2003-2008	0.704**	0.618**	0.761**	0.752**	1.191**	0.871**	0.866**	0.480**	0.326**	0.931**	0.390**	0.665**
	0.556	0.441	0.497	0.835	0.548	0.658	0.635	0.795	0.686	0.585	0.723	0.538
1999-2008	0.688**	0.554**	0.737**	0.751**	1.086**	0.782**	0.312**	0.420**	0.338**	0.506**	0.382**	0.614**
	0.655	0.556	0.584	0.847	0.679	0.719	0.360	0.584	0.684	0.495	0.512	0.482
2010-2014	0.919**	0.542**	1.104**	1.010**	0.641**	0.658**	0.766**	0.628**	0.0628	0.366**	0.521**	0.0837**
	0.807	0.923	0.885	0.716	0.956	0.800	0.547	0.771	0.008	0.598	0.428	0.114

Coefficient estimates shown in first row

R squared shown in following row

** p<0.05, * p<0.1

Table 3.7 Sample Split Monthly (Short Run) First Difference Regressions

	Austria	Belgium	France	Germany	Italy	Luxembourg	Netherlands	Finland	Ireland	Portugal	Spain	Greece
1999-2003	0.244**	0.445**	0.564**	0.584**	0.366	0.177*	0.0893	0.507**	0.250**	-0.135	0.0889	0.242**
	0.111	0.489	0.575	0.577	0.094	0.111	0.013	0.511	0.227	0.031	0.021	0.315
2003-2008	0.340**	0.332**	0.599**	0.546**	0.344**	0.468**	0.385**	0.310**	0.320**	0.160**	0.601**	0.181*
	0.302	0.393	0.595	0.522	0.132	0.382	0.175	0.215	0.231	0.051	0.604	0.089
1999-2008	0.305**	0.372**	0.579**	0.561**	0.351**	0.288**	0.228	0.390**	0.281**	0.0413	0.311**	0.208**
	0.213	0.427	0.580	0.545	0.115	0.211	0.073	0.326	0.225	0.003	0.209	0.151
2010-2014	0.243**	0.422**	0.727**	0.657**	0.397**	0.365**	0.307**	0.263**	0.246**	0.238**	0.407**	0.102**
	0.096	0.363	0.417	0.459	0.267	0.298	0.157	0.132	0.205	0.302	0.577	0.101

Coefficient estimates shown in first row

R squared shown in following row

** p<0.05, * p<0.1

Table 3.8 Sample Split Quarterly (Medium Run) First Difference Regressions

	Austria	Belgium	France	Germany	Italy	Luxembourg	Netherlands	Finland	Ireland	Portugal	Spain	Greece
1999-2003	0.366**	0.485**	0.776**	0.737**	0.828**	0.493**	0.192	0.589**	0.321**	0.0362	0.136*	0.280**
	0.156	0.625	0.760	0.751	0.352	0.445	0.052	0.569	0.459	0.002	0.058	0.209
2003-2008	0.469**	0.355**	0.673**	0.709**	0.796**	0.639**	0.613**	0.405**	0.299**	0.453**	0.603**	0.433**
	0.483	0.367	0.737	0.656	0.370	0.576	0.424	0.290	0.244	0.296	0.732	0.385
1999-2008	0.439**	0.409**	0.700**	0.718**	0.802**	0.564**	0.404**	0.475**	0.311**	0.257**	0.338**	0.374**
	0.334	0.470	0.727	0.696	0.357	0.507	0.205	0.395	0.337	0.100	0.295	0.301
2010-2014	0.456**	0.495**	0.963**	0.861**	0.656**	0.622**	0.403**	0.401**	0.333**	0.292**	0.410**	0.109**
	0.313	0.611	0.639	0.639	0.648	0.591	0.216	0.363	0.441	0.423	0.596	0.100

Coefficient estimates shown in first row

R squared shown in following row

** p<0.05, * p<0.1

Figure 3.1 Interest Rates

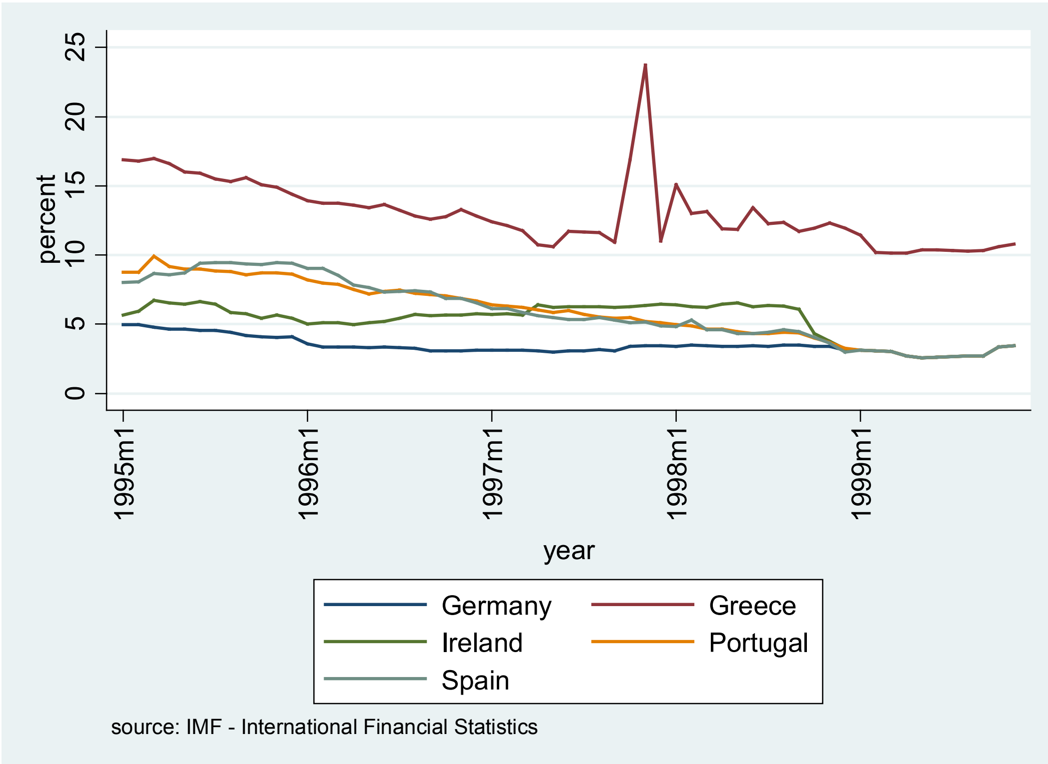


Figure 3.2 Current Account

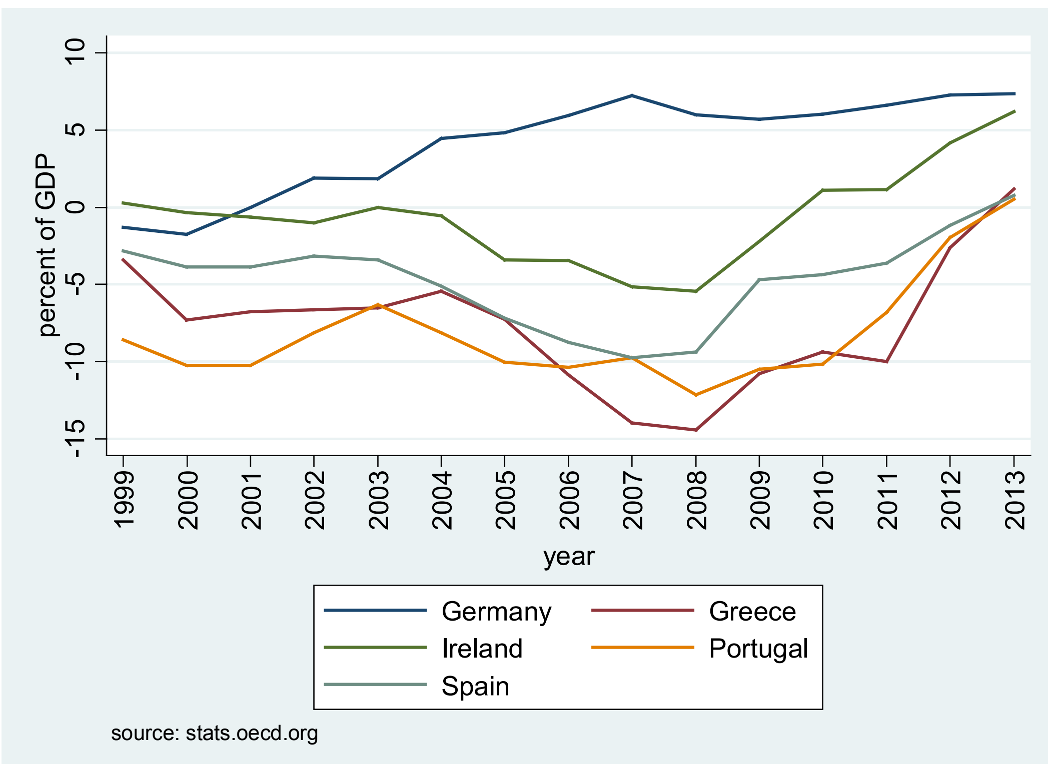


Figure 3.3 Industrial Production Index 2010 = 100

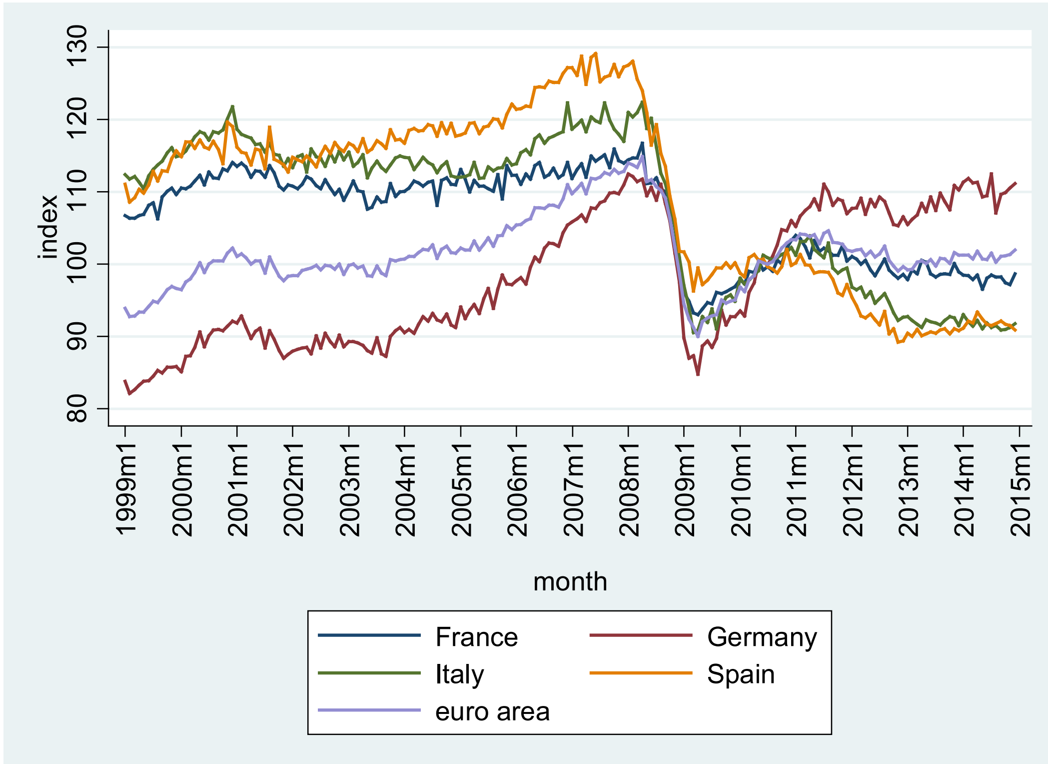


Figure 3.4 Unemployment Rates 1

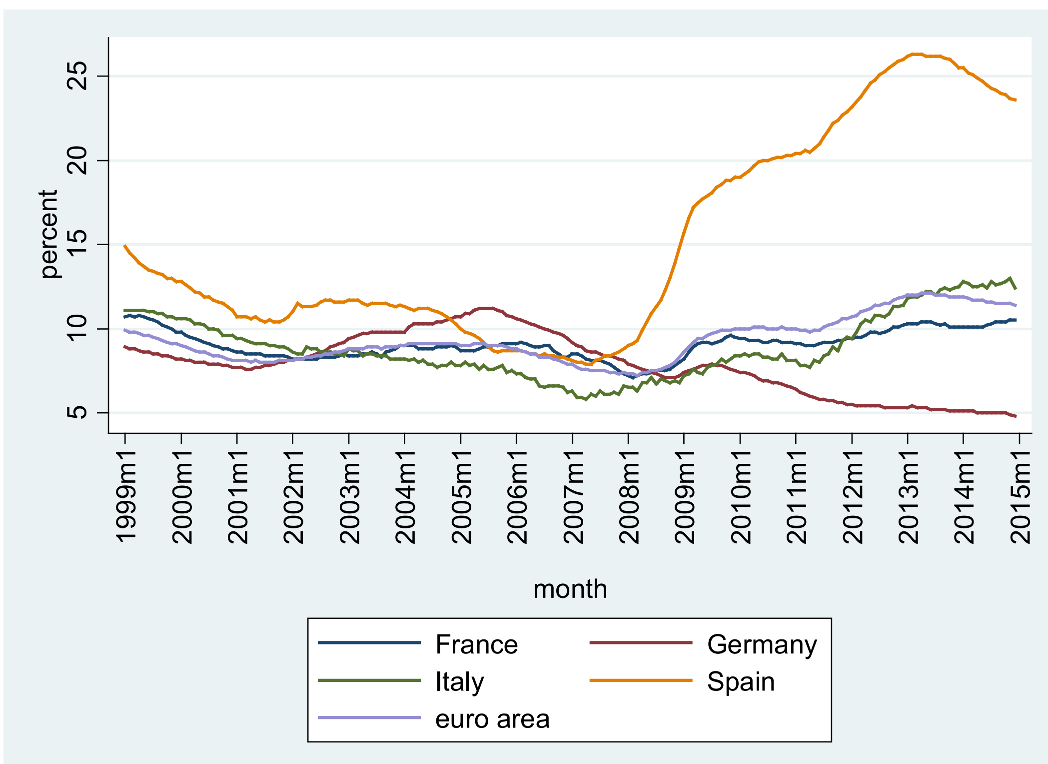


Figure 3.5 Unemployment Rates 2

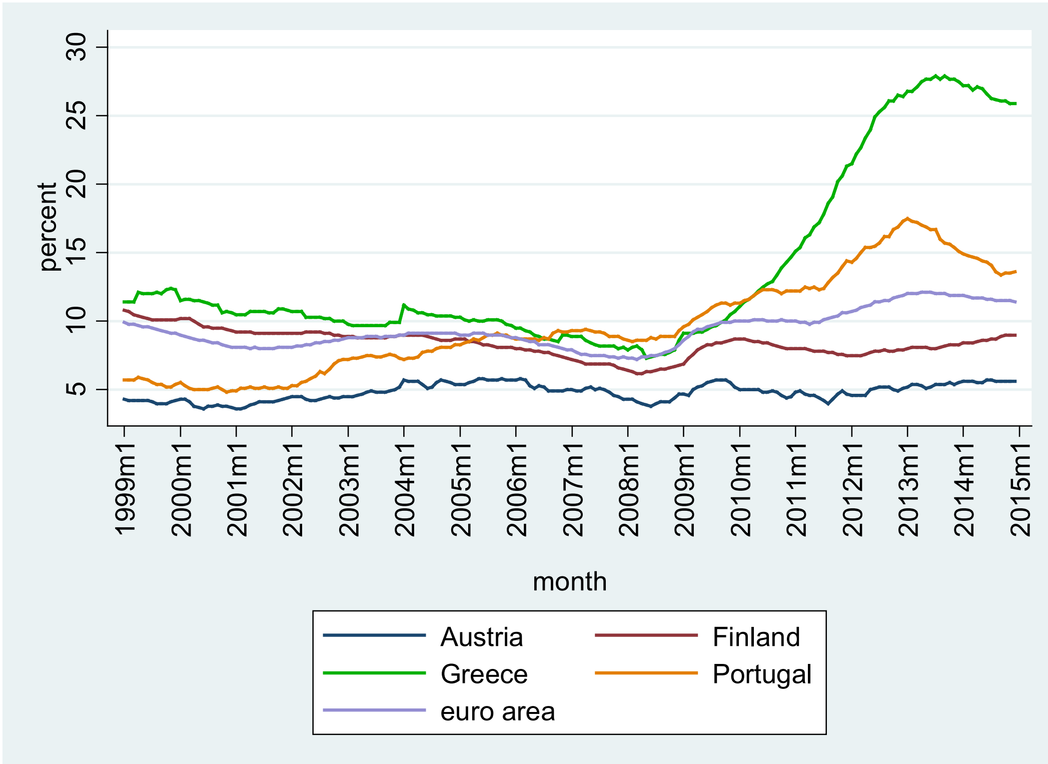


Figure 3.6 Unemployment Rates 3

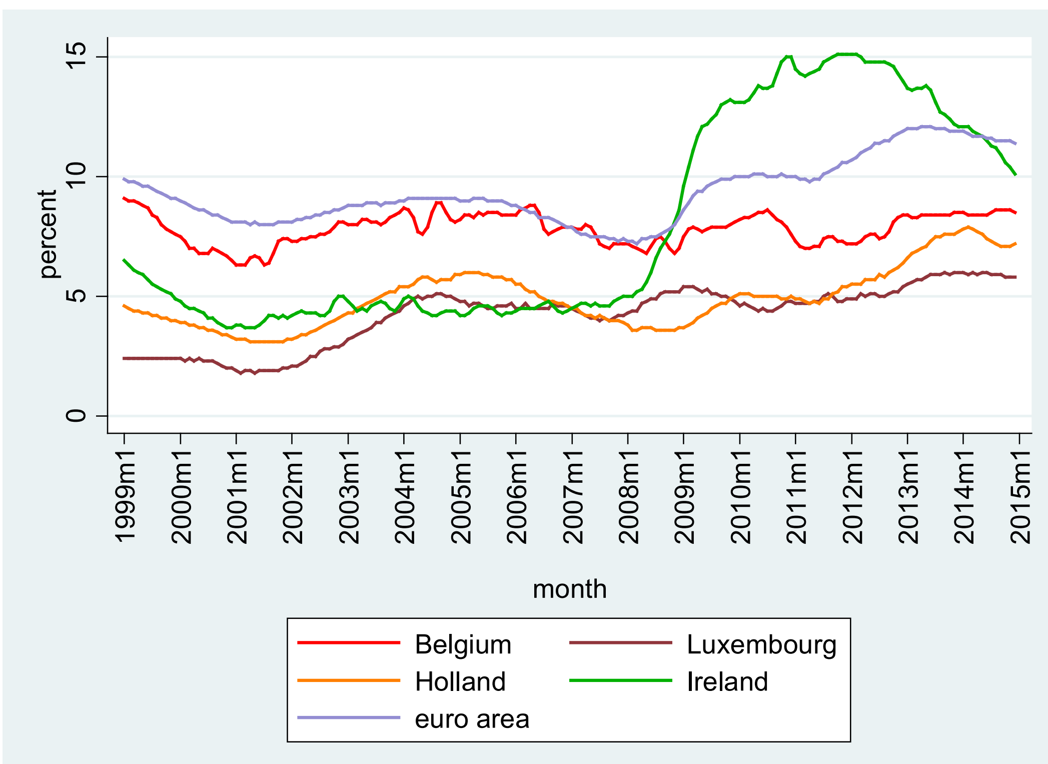


Figure 3.7 Inflation Rates 1

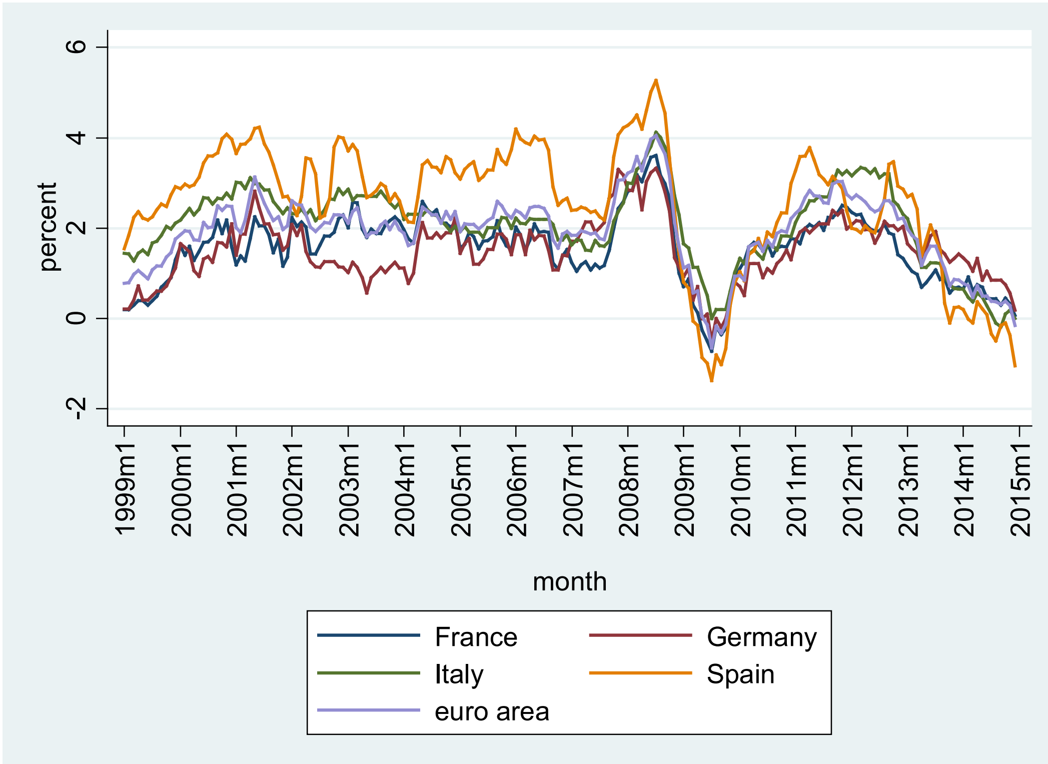


Figure 3.8 Inflation Rates 2

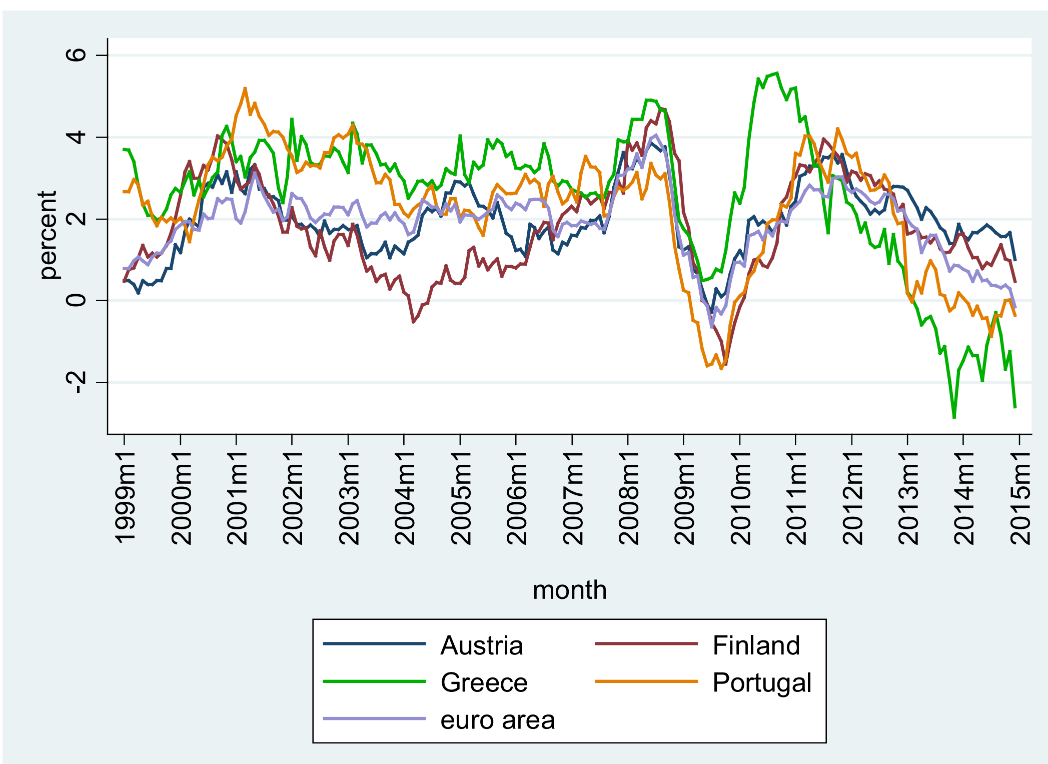


Figure 3.9 Inflation Rates 3

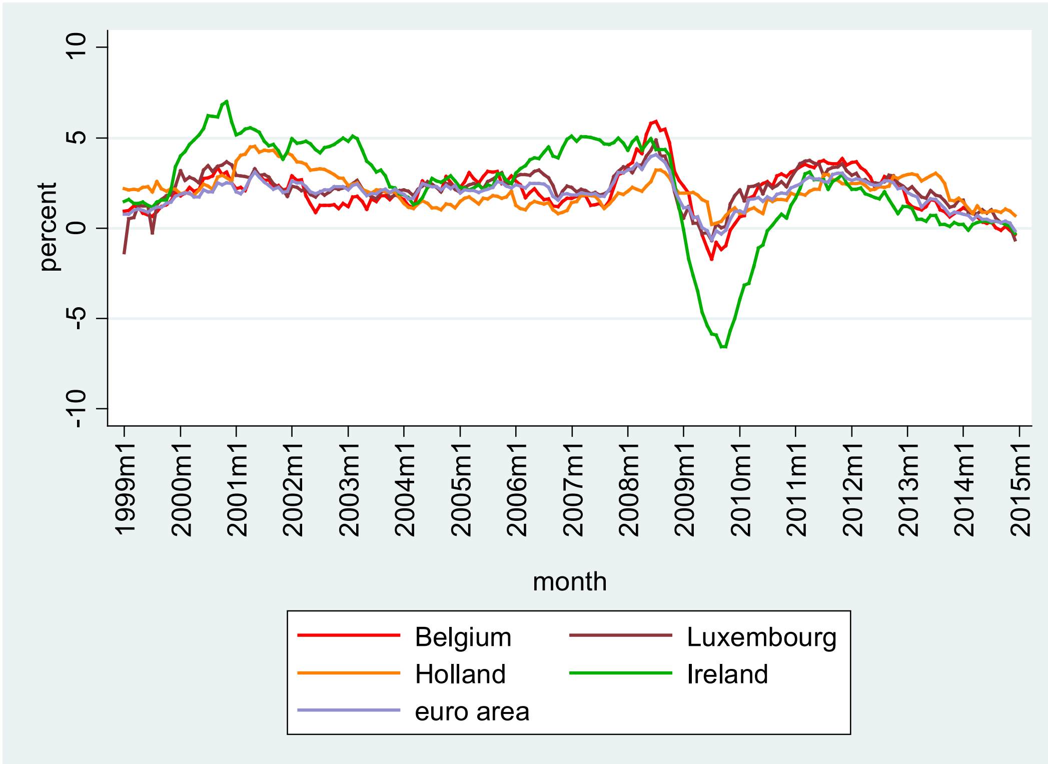


Figure 3.10 Desires Interest Rates 1

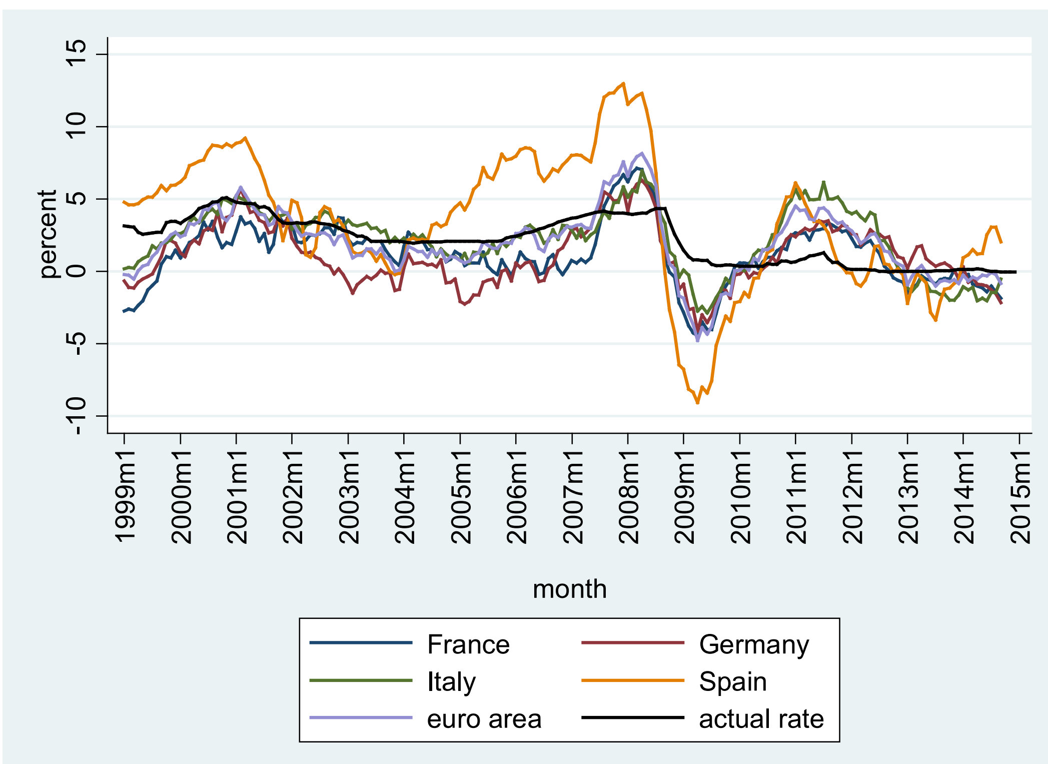


Figure 3.11 Desired Interest Rates 2

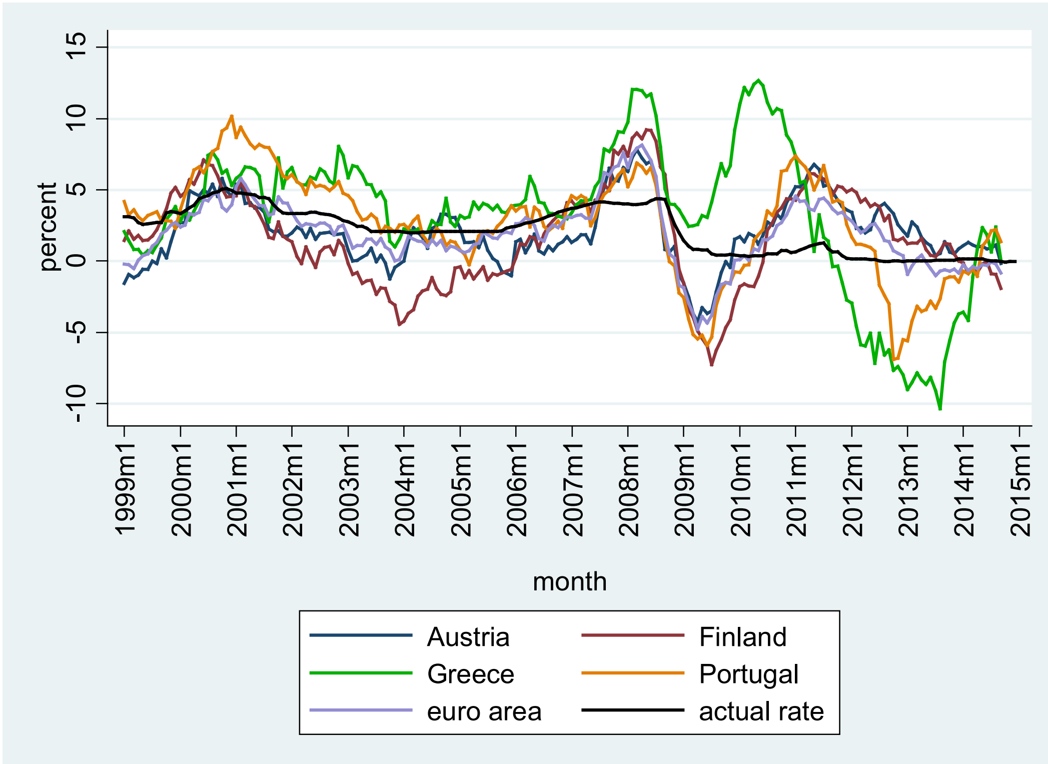
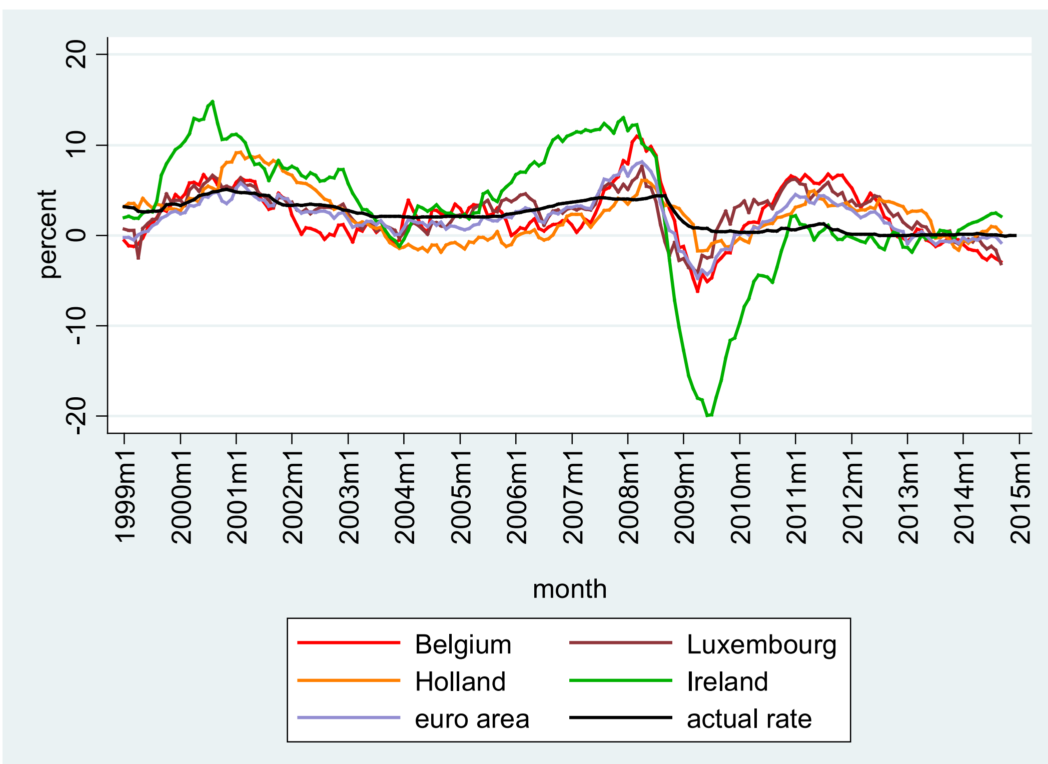


Figure 3.12 Desired Interest Rates 3



4 Monetary Independence and Capital Controls: The Case of Asian Countries

4.1 Introduction

As stated in Obstfeld, Shambaugh, and Taylor (2005) open economy countries have a desire for a stable exchange rate, free capital mobility and a monetary policy oriented towards achieving domestic goals (monetary independence). However, according to monetary policy trilemma, only two out of the three goals are possible at any given time. For example, if a country has a fixed exchange rate regime, then it will have to impose capital controls in order to achieve monetary independence. If a country has a fixed exchange rate regime and wants to keep its economy free of capital restrictions, then it must follow the monetary policy of the foreign country and will hence lose its monetary independence. If the country wants to pursue an independent monetary policy free of capital restrictions then it must have a flexible exchange rate regime.[47]

In order to achieve monetary independence goals, restricting capital mobility might not be beneficial because economic theory suggests that free capital mobility will lead to optimal allocation of resources and should therefore be pursued (Ostry et al. 2010). However, the IMF (2012) has recently concluded that capital controls are useful for calming volatile capital flows in emerging economies. Likewise, Magud et al. (2011) states that large capital inflows to emerging markets may cause exchange rate appreciation and fuel asset price bubbles; when there is a reversal and capital starts leaving (outflow), this can lead to large currency depreciation and an economic downturn such as the 1997 Asian financial crisis. Recently, it has been argued that in a world with globalized capital markets maintaining monetary independence without capital controls has become more difficult. Rey (2015) argues that the only way to

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[47] Some mixture of intermediate regimes may be considered. It is important to note that the trilemma hypothesis emphasizes the tradeoff among the three goals.

achieve monetary independence is through imposing capital controls, regardless of the exchange rate regime. This suggests that the trilemma has turned into a dilemma between free capital mobility and monetary independence.

In this paper we attempt to quantify all the variables of the trilemma and to investigate the relationships among the three - monetary independence, exchange rate flexibility, and capital controls. All three objectives are more or less conceptual and need to be quantified for empirical study. Although there are no agreed-upon methods, existing studies fall into a couple of broad categories.

The first category includes Frankel et al (2004), Shambaugh (2004), Obstfeld et al. (2005), Bluedorn and Bowdler (2010), and Klein and Shambaugh (2015). In these papers, the first step in testing the trilemma is through obtaining a measure of monetary independence. In general this is done by having a large sample of countries in a panel regression where the home country interest rate is regressed on its anchor or base interest rate (generally the U.S. federal funds rate). The regression fit and the coefficient magnitude then determine monetary independence. In general if there is a good regression fit and a base rate coefficient close to one, then the country is considered monetarily dependent on the base country, and if there is a poor fit, it is considered monetarily independent. [48] The measures of capital controls in these papers are usually taken from IMF databases – they are annual, de jure, and usually coded as yes or no; sometimes the sample is simply split based on years that were known to have capital controls. Similarly for exchange rate flexibility, the country is coded by a binary variable and generally based on high or low volatility in the exchange rate over the given year. There are a few ways capital controls and exchange rate flexibility are taken into account by the monetary independence result; either the sample is split in accordance to yes or no measures of capital controls and exchange rate flexibility or sometimes the sample is not split but dummy variables are used in representing these. In general, the results show that countries with exchange rate flexibility and capital controls have an

[48] See eq. (2) in section 3 of this paper.

interest rate that does not closely follow the U.S. rate thus indicating monetary independence. On the other hand countries that have a fixed exchange rate without capital controls have an interest rate that more closely follows the U.S. thus indicating monetary dependence.

The second category includes Aizenman et al. (2010) and You et al. (2014). Here the authors measure monetary independence as the annual correlation of monthly interest rates. Exchange rate flexibility is measured as the standard deviation of monthly exchange rates for each year. Capital controls are annual and either taken from the Chinn- Ito Index (see Chinn-Ito, 2008) or are based on Shindler (2009) both of which are in turn constructed from the de jure IMF – Annual Report on Exchange Arrangements (AREAER). To test the trilemma, You et al. (2014) regress the monetary independence measure on capital controls and exchange rate regime in a panel regression. They find evidence that flexible exchange rate regimes and various measures of capital controls positively influence monetary independence.

The above trilemma tests generally employ de jure measures of capital controls and measures of exchange rate flexibility that are somewhat too coarse and loosely related to theory. For our tests of the trilemma, we develop a methodology that is more in accordance with theory. The methodology is summarized in the next section. To see how our measures fit with real world data we choose the Asian countries. These countries are highly integrated to international capital markets as evidenced by the strong effects during the Asian financial crisis. But since the crisis, different countries have adopted different types of capital controls and have different exchange rate regimes. There are countries that have no capital controls and exchange rate flexibility (Japan) and countries with no capital controls and a firmly pegged exchange rate regime with the U.S. dollar (Hong Kong). There are also countries that have strict capital controls (China). Table 4.1 summarizes the countries based on their exchange rate regime, their standard deviation of actual exchanges rates (in logs), and KAOPEN – the

Chinn-Ito de jure capital controls index – where a larger number indicates more controls.

This paper has two main objectives. First, we present continuous time-series estimates of capital controls for the Asian countries. Second, we construct an improved measure of monetary independence based on the model that includes the desired or optimal interest rate as well as the base interest rate. We use the Taylor rule interest rate as the desired rate. In standard monetary independence regressions a country following the base interest rate is considered monetarily independent. Such models may be miss-specified to the extent that a country can follow its own "independent" monetary policy that turns out to be very similar to that of the base country (the U.S. or Germany).

The rest of this paper is organized as follows: In the next section we present our trilemma measure and show graphical results for the Asian Countries. In section 4.3, we construct monetary independence tests using a traditional regression for each country. We then observe how monetary independence is influenced by our measure of exchange rate regime and capital controls. In section 4.4, we modify the monetary independence tests to include the Taylor rule interest rate and a show a VAR for short run results. Section 4.5 concludes.

4.2 Measuring the Trilemma

As mentioned in the above papers, there is no agreement as to how each component of the trilemma is measured. In the literature, capital controls are measured from the de jure index provided by the IMF, and the exchange rate regime is measured by a de jure classification of the IMF or by an annual deviation measure of the actual exchange rate. The good news is that the trilemma has a theoretical foundation. In theory the link between the base country interest rate (generally assumed to be the U.S. federal funds rate) and the home country interest rate can be expressed as a capital control augmented interest rate parity condition. Klein and Shambaugh (2015)[49] consider:

$$i^H = i^B + E[\Delta s] + k$$

where i^H is the home country interest rate, i^B is the base country interest rate, $E[\Delta s] = E_t[s_{t+1}] - s_t$, is the percentage change in the expected exchange rate from the spot rate, and k are capital controls. From this equation, monetary independence is generally measured by the differences in movement between the base country interest rate and the home country interest rate. Highly correlated movements indicate similarity in monetary policy and therefore the home country is considered monetarily dependent on the base country. If there are differences in movement between the interest rates, then this is either due to changes in $E[\Delta s]$ or changes in k.[50]

To obtain the trilemma measures we closely follow Ma et al. (2004), Ma and McCauley (2008), and Kohli (2012). In these studies, the authors argue that the non-deliverable forward (NDF) rate can be used to measure expected exchange rates and therefore the existence of capital controls. The NDF market in Asia emerged in the late 1990s after the Asian financial crisis when restrictions were placed on foreigners in the onshore forward market. The NDF market is a forward market where physical currencies are not exchanged and the transactions are settled in dollars.[51] The advantage of the NDF market is that it is offshore and not restricted by the home country; it is therefore argued that it could be used to measure expected exchange rates and therefore the existence and intensity of capital controls. In particular, the authors compute an imputed rate $i^I = i^B + \ln(NDF) - \ln(S)$, where NDF is the NDF exchange rate against

[49] See p.4 of the NBER working paper version.

[50] It is important to note that the interest rate linkage and monetary independence are based on expected, not actual, exchange rate changes. For example if a country has declared a pegged exchange rate, even if there are no capital controls ($k = 0$), it may still have some monetary independence to the extent that it can influence an expected exchange rate different for the spot exchange rate; in this case its exchange rate regime is not credible.

[51] See appendix F for NDF market details. Theoretically the NDF is supposed to equal the expected future exchange rate. If they are not equal then we know that the expected future exchange rate is pinned down by interest rate parity - if the NDF rate is different than that, then there would be arbitrage opportunities by signing a forward contract and moving capital from one country to the other.

the dollar, and S is the spot exchange rate. Ma et al. (2004) and Ma and McCauley (2008) also argue the difference between the actual home interest rate and the imputed rate measures capital controls, viz., $k = i^H - i^I$, because k, if positive, can be seen as an ad-valorem tax equivalent on inflows. On the other hand, a negative k represents an ad-valorem tax equivalent capital control on outflows. Replacing for the imputed rate, a capital control augmented covered interest parity is obtained:

$$(1) \qquad i^H - i^B = \Delta f + k$$

where $\Delta f = \ln(NDF) - \ln(S)$ is the forward discount on the home currency. This is the same condition as the previous interest rate parity condition but with the NDF rate replacing the expected future exchange rate.

The above condition summarizes the trilemma. It can be best illustrated by examples. (A) Under a credibly fixed exchange rate ($\Delta f = 0$) and free capital mobility ($k = 0$), a country has no monetary independence ($i^H = i^B$). (B) To gain monetary independence ($i^H \neq i^B$), it needs to impose some restrictions on capital movement ($k \neq 0$) or move towards a more flexible exchange rate system ($\Delta f \neq 0$). [52]

4.2.1 Data and Graphs

In our empirical study we use data on ten Asian countries – China, Malaysia, Japan, India, Indonesia, Philippines, Thailand, Korea, Singapore, and Hong Kong. The choice of countries is based on data availability which spans from 1999 to 2015 and includes interbank interest rates, nominal dollar exchange rates, inflation, industrial

[52] In the real world, capital controls are not the only reason covered interest parity will be violated; there might also be risk related reasons. First, if there is counterparty risk in the forward exchange market so that some of the contracts are not fulfilled then this will discourage capital flows. If this risk is present then it will influence the forward rate and then be part of computed capital controls. To overcome the risk, this paper uses data (where possible) from the less risky offshore NDF market rather than the onshore forward market. As the forward transactions in the NDF market are settled in dollars, there is less risk because the principle amounts do not move and currency does not need to be physically exchanged. See Lipscomb (2002) and Shamah (2008) for details. A second type of risk is country investment risk. From the example, risk on investment in the home country will also discourage inflows. To solve this problem, we follow Shambaugh (2004) and assume that this risk stays constant over time. The overall results of this paper are determined by the movements in capital controls and interest rates over time; constant risks will not change the results.

production and unemployment. NDF market rates are available for five countries – China, India, Indonesia, Philippines, and Korea. For the rest, the onshore forward market rate is used.[53] The 3 month U.S. interest rate is used as the base rate. A complete data description is available in Appendix E.

To measure the trilemma components - First, the spot and NDF exchange rate data are used to compute the Δf. Then using data on interest rates we compute the capital controls measure k from eq. (1). Figures 4.1-4.10 show graphical results for all countries. The top portion of the graphs has the U.S. base rate, the home country rate, and the Taylor rule rate for the home country (to be discussed in section 4.4). The bottom portion has the interest rate differential $(i^H - i^B)$, exchange rate difference (Δf) along with the de jure measures of capital controls on inflows (green) and outflows (yellow) taken from Shindler (2009) and You et al. (2014). For the latter, a higher value represents more controls given on the right hand axis. The difference in the dark blue and dark red curves represents deviations from covered interest parity (CIP) and thus represents capital controls in our measure. When the blue line is above the red then $i^H - i^B > \Delta f$, and so there are controls on inflows ($k > 0$), otherwise there would be arbitrage opportunities by borrowing from abroad and investing in the home country. When the blue is below the red, then the difference represents controls on outflows ($k < 0$).

These figures provide the first evidence for the trilemma. It appears that China (Figure 4.1) and Japan (Figure 4.3) have interest rates that are relatively steady compared to the U.S; therefore, they can also be considered monetarily independent as shown in the results of the next section. However, Japan has almost no capital controls and the differences in the interest rate movements are achieved mainly through exchange rate flexibility. China is known to have used capital controls extensively; see Ma and McCauley (2008) and Cecchetti and Schoenholtz (2014). Our results also

[53] There are no NDF markets for the Japanese yen, the Hong Kong dollar, or the Singapore dollar as cross-border capital flows are largely free from government restrictions. Further, Thailand does not have an NDF market (see Appendix F), and the Malaysian time series are too short as their NDF market for their currencies were only developed recently.

indicate that markets have expected a great deal of exchange rate movement. On the other extreme, Hong Kong has a currency board with U.S. dollar since 1983 and almost no capital controls. Its interest rate moves very closely with the base rate (of the U.S.). This is a typical case of a monetarily dependent economy.

These examples show the effects of the trilemma – monetary independence can be achieved with either exchange rate flexibility (Japan) or capital controls (China), but if the country has neither (Hong Kong) it must be monetarily dependent.

4.2.2 Comparing Capital Controls

This subsection briefly compares our de facto measures of capital controls to de jure measures and media reports on capital controls. One problem with the de jure measures of capital controls is that they only measure government's official restrictions which may not necessarily be consistent with the actual level of capital controls. The bottom of Figures 4.1-4.10 provide a comparison of our de facto measures with the Schindler (2009)-type de jure measures.[54] De jure measures are in step changes as they are only annually provided. The scale, as shown in the right side of the bottom figures, is from 0 to 1 with 1 being the most controlled.

Sometimes when there are de jure controls they might not be effective (produce CIP deviations) and so they might not correspond well with our de facto measure, but we should expect that when the de jure measures are 0 then so would our de facto measure. In other words when there are no de jure capital controls, the CIP condition should hold almost exactly. This is evidenced by Japan from 1999-2006 in Figure 4.3; as we can see during this period there were no de jure controls on outflows and inflows, correspondingly we also see that the blue and red curves are almost on top of each other. We also see that Japan had effective capital inflow restrictions before 1999 (during Asian financial crisis). During this time period the green curve is a bit higher and consistently our de facto measure shows that the red curve is mostly below the blue.

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[54] See You et al. (2014) for information regarding the construction of de jure measures employed in the Chinn-Ito Index, and Schindler (2009).

Further, we also see that it is not until the increase in the inflow controls during 2008 that there is a difference between the blue and red curves thus indicating that the 2008 de jure inflow control is also effective. In marked contrast to Japan, China has had strong capital controls throughout the whole period according to the de jure measures. Our de facto measure shows their effectiveness more precisely through the varying deviations between the interest rate differential and the forward discount. We also find the evidence of some capital controls that are not reported in the de jure index. (For instance, Singapore seemed to have effective controls on outflows in the 2004 period.)

Table 4.3 also lists some important government announcements. Thailand tightened its capital controls in 2003 and during 2006-2008, both controls seem to work as there was an intermediate spike in the difference between interest rate differential and the exchange rate differential. Indonesia tightened its capital controls in 2001, 2006, and 2009 respectively, but the 2009 one is most effective because there was an intermediate spike in the difference between interest rate differential and the exchange rate differential. India, Korea and Hong Kong also imposed some restrictions on capital flows during and after the 2008-2009 financial crisis. However, their effects are not as strong as Indonesia and Thailand. Because this was during the crisis, it is possible that there was increased exchange rate risk and country risk, both of which could have produced the results. However, it is also possible that there was expected future depreciation and the government imposed controls to prevent its currency from actually depreciating; this is discussed in the next section. In summary, our de facto measure captures capital controls well, and more importantly, provides more accurate information about the effectiveness and dynamics of capital controls than de jure measures.

4.3 Monetary Independence and the Effects of Capital Controls

How do capital controls contribute in achieving monetary independence? Conventional wisdom (until recently) is that capital controls are largely ineffective. More recently, economists including IMF (2012) have started giving more positive views on capital controls. Rey (2015) argues that capital controls are required to achieve independence regardless of exchange rate flexibility. This section first conducts monetary independence tests and then compares the variance of capital controls to the variance of exchange rate changes to determine which component dominates.

4.3.1 Monetary Independence

For a measure of monetary independence, we closely follow the methodologies of Frankel et al. (2004) and Shambaugh (2004). Consider first the conventional regression:

$$(2) \quad i_t^H = \alpha_1 + \alpha_2 i_t^B + e_t$$

If the coefficient α_2 and the R squared are both close to 1 then the home country rate moves with the foreign country rate and the home country is therefore considered monetarily dependent. On the other hand when they are both near zero we can conclude that there is little or no relationship and the home country is considered monetarily independent.

Table 4.2 shows the results of the Augmented Dicky-Fuller test for all interest rates using the lag length selected by the Ng-Perron (2001) criteria. The results show that interest rates are stationary to at the 10% level with the exceptions of India, China, Indonesia, and Malaysia.[55] Interestingly, the base rate (of the U.S.) appears the most stationary of all rates. As the results of the unit-root test are split, we proceed to estimate eq. (2) in levels and report the results in Table 4.4. This could be interpreted as a cointegration regression if the interest rates are nonstationary indeed. (In a later section, we also consider the results of estimation of eq. (2) in differences and also using a VAR model with an error correction term.)

Table 4.4 reports the regression results for eq. (2). The results are listed from countries that are the most independent to least independent. As there are two components that determine independence – correlation (R squared) and magnitude

[55] These are non-stationary, however they do not show a strong relationship with the base rate.

(the α_2), the table lists the countries from the least correlated interest rates. China, Malaysia, India, and Japan appear to be the most independent. These are followed by Indonesia, Philippines, Thailand, and finally Korea, Singapore, and Hong Kong which appear to be the most dependent. An interesting case is Indonesia which shows a significant coefficient close to 1 but a poor R squared.[56]

4.3.2 Exchange Rate Changes or Capital Controls?

The above regression states that for monetary independence to exist there must be differences in the movement between the base rate and the home rate. Differences in interest rate movement imply that there must be variation in the interest rate differential. As shown in eq. (1), this variation will depend on the variation in the capital controls (k) and the variation in the forward premium (Δf). Table 4.5 reports a summary of the sample standard deviations for these components. The first row lists the standard deviation in the capital controls for each country, the second is the standard deviation of Δf, and the third is the standard deviation in the interest rate differential $(i^H - i^B)$. The last row is the standard deviation of actual exchange rate changes that are based on Table 4.1.

As we can see the results from the monetary independence regressions tend to be consistent with the interest differential in that the higher the variation in the differential the lower the monetary independence. It appears that based on this measure, Thailand, Korea, Singapore, and Hong Kong are the most dependent on U.S. policy. Except for Thailand, these countries have low capital controls and grater exchange flexibility. We also see that the most independent countries rely either mostly on capital controls (China), or exchange flexibility (Japan), or combinations of both.

Thailand and Indonesia seem to be exceptional. Thailand has high capital controls and exchange rate flexibility but nevertheless has relatively low to medium degree of monetary independence. As we can see from Figure 4.7, this result is mainly

[56] It turns out that its desired interest rate explains much of home rate variation and α_2 actually turns negative when the desired rate is included.

due to the large controls on inflows imposed by Thailand around the 2006-2008 period in order to keep the actual exchange rate (not graphed) from appreciating. Theoretically from eq. (1), if there are large inversely related movements between Δs and k the interest rate stays about the same. As we can see from the figure, this explains why Thailand had a rather low interest rate differential but large variations in Δf and k. The scenario is similar for Indonesia for the 2008-2009 period but due to actual exchange depreciation pressure, the authority imposed controls on outflows instead.[57]

Overall the results are consistent with what can be discerned from the graphs. They suggest that the trilemma is valid for this group of Asian countries. Simply put, both exchange rates and capital controls play a role in explaining the differences in movement between home and base rates. We see that for all countries except China, exchange rate flexibility actually explains most of the interest rate differentials. The results also are consistent for countries with known exchange regimes and capital controls. For instance, countries that have low exchange rate flexibility and low capital controls (Korea, Singapore, and Hong Kong) tend to be the most monetarily dependent, while those that have higher exchange flexibility and capital controls generally have more monetary independence.

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[57] For a possible explanation consider the interest rate parity condition: $i_t^H - i_t^B = E_t[s_{t+1}] - s_t + k_t$. Suppose initially all variables are at 0. Normally, we think that when there is an i_t^H increase there would be capital inflows and s_t would appreciate (decrease) until there are no more arbitrage opportunities. In order to prevent some of the appreciation the government can impose capital controls on inflows $k_t > 0$. In this case all variables $(i_t^H, E_t[s_{t+1}] - s_t, k_t)$ move in the same upward direction. Now in the case of Thailand there was no change in the interest rate but there was some exchange rate appreciation starting around the 2006 period (perhaps due to foreign direct investment), perhaps this put pressure on the expected future exchange rate to appreciate so that $E_t[s_{t+1}]$ decreases, if the government does not want to change its current interest rate then more capital will flow in thus putting pressure on the spot exchange rate (s_t) to also appreciate (to eliminate arbitrage opportunities). If the government wants to stop s_t from appreciating it could impose capital controls on inflows as Thailand did. As $E_t[s_{t+1}] - s_t$ remains negative due to the capital controls we see that these two terms move in opposite directions. In the case of Indonesia, perhaps the wake of the financial crisis made their rupiah currency uncertain. This put pressure on $E_t[s_{t+1}]$ to increase (depreciate). If the government wants a steady interest rate then this uncertainty would put pressure on s_t to depreciate as well (to eliminate arbitrage opportunities). To avoid s_t depreciation the government imposed large outflow capital controls during this time period. The case for India, China, and the Philippines is similar during this time period.

4.4 Alternative Tests of Monetary Independence

In the previous section, we investigated the trilemma relationship using a de facto measure of capital controls and a new measure of exchange flexibility but kept the traditional monetary independence regression (since it was also part of the same interest rate parity theory). In this section, we argue that perhaps a more appropriate measure of monetary independence should also include a measure of the country's desired policy interest rate. Further, as the previous results were in levels regressions, we try to establish causality and also run a VAR model. Lastly this section concludes by comparing our results with a few recent papers from the monetary independence literature in Asia.

4.4.1 The Taylor Rule as the Desired Interest Rate

In an economically integrated world countries may go through similar business cycles for various reasons. Traditional monetary independence regressions do not take into account whether correlated movements of the interest rates may be due to the similarities in economic conditions and economic policies instead of a causal relationship. We thus include the country's desired interest rate that would be chosen by its central bank in the absence of the external pressure from the base country. This is similar to Klein and Shambaugh (2013) who incorporate inflation and GDP growth in their regressions. Following Taylor (1993), we approximate the desired interest rate with the Taylor rule (TR).

The TR interest rate is normally estimated from the actual data on inflation and output gap as follows: $i_t^H = \beta_1 + \beta_2 \pi_t + \beta_3 y_t + e_t$, where π_t is the rate of inflation, and y_t is the output gap – the percentage deviation of actual output from its full-employment level. The fitted value of i_t^H is generally seen as the TR interest rate. Alternatively, one may obtain a TR rate using the parameters, $(\beta_1,\ \beta_2,\ \beta_3 = 1.0,\ 1.5,\ 0.5)$, originally suggested by Taylor (1993). To be consistent across countries we use the original parameters from Taylor (1993). As a robustness check we also estimate the Taylor rule for each country but the overall results remain similar. We follow Clarida, Gali, and Gertler (CGG, 1998) and employ IMF data on CPI inflation and industrial production (or, if not available, unemployment). The cyclical component of a Hodrick-Prescott filter is used on the log of deseasonalized industrial production to obtain the output gap. Unlike actual policy interest rate, the resulting TR interest rates are extremely volatile. This is not surprising as central banks tend to smooth interest rates (See CGG, 2000). We smooth the TR rate using a coefficient of .9.[58]

The TR interest rates are reported in the top portion of Figures 4.1-4.10, and it seems most countries only loosely follow the Taylor rule. A modified regression including the desired interest rate (i_t^D) is estimated as follows:

$$(3) \quad i_t^H = \alpha_1 + \alpha_2 i_t^B + \alpha_3 i_t^D + e_t$$

Table 4.6 reports the results. The coefficient estimate for the base rate remains largely unaffected with the exception of Indonesia. The coefficient on the desired rate is significant and correctly signed (positive) in five countries including China, Japan, India, Indonesia, and Thailand. There is also a significant improvement in the regression fit in those countries except China.

Two cases – Indonesia and India – are interesting.

Without considering the desired rate, Indonesia appears to have a one to one relationship with the base rate (Table 4.4). In the presence of the desired rate, however, its interest rate is almost exclusively determined by the desired rate and the coefficient on the base rate turns negative. This may be an indication that monetary policy making in Indonesia is more autonomous than what Table 4.4 implies.

As can be seen, the regression fit is also improved for India, and unlike Indonesia, the base coefficient is actually higher after including the desired interest rate and so India is actually more monetarily dependent. The estimates indicate that India follows both the base rate and its desired rate. The base coefficient can be interpreted: holding

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[58] This parameter is taken from Clarida, Gali, and Gertler (1998), who report the parameter of different countries to lie between .87 and .95. The results remain similar if smoothing parameters in these ranges are used. To smooth the TR interest rate we use the formula: $i_t^{T\,smooth} = 0.9\, i_{t-1}^{T\,smooth} + 0.1\, i_t^{T\,actual}$

the desired rate constant, a 1 percentage point increase in the base rate will increase the home rate by .57 percentage points. Figure 4.4 for India also confirms these results; it appears that before 2008 India closely follows its Taylor rule. After 2008 we see that India lowered its interest rate thus following the base rate; this appeared to cause the economy to overheat and inflation to rise thus further increasing the desired interest rate. India finally started raising interest rates in 2010 and thus deviated from the base rate.

4.4.2 Short-Run Effects

This subsection follows Cheung et al. (2008) and uses VAR analysis to establish causality and other relationships in the short to medium run. The first VAR uses the base rate and the home rate in first differences. The Bayesian Information criterion (BIC) for most countries indicates two lags as optimum. To be consistent across countries two lags are used for all countries. There is also an option to use a vector error-correction model (VECM) but it is not reported as the interest rates are not cointegrated with the base rate with or without adding the desired rate as reported by the Engle-Granger cointegration tests in Table 4.7.

The results showing variance decompositions after the 3-month (short-run) and 3-year (medium-run) horizons of the home interest rate explained by the shocks from the base rate and the home rate are shown in the first two columns of Table 4.8. Base-rate shocks explain more than half of the variations in the home interest rate in the medium run in Hong Kong, Singapore, and Korea. On the other hand, they play a minimal role in China and Malaysia. Relative to the regression results it appears that Japan follows the U.S. rate more in the short run.

The next three columns show results from a VAR with the desired interest rate included. It is ordered before the home rate on the assumption that it could contemporaneously affect the home interest rate.[59] The addition of the desired interest rate substantially reduces the contribution of the base shocks in Korea, Singapore, and Hong Kong. In four countries – India, Thailand, Korea, and Singapore – the shocks from the desired rate explain more than 20 percent of the variation in the home rate. Four additional countries – Malaysia, Japan, Philippines, and Hong Kong – are responsible for more than 10 percent of home rate variations. In only China and Indonesia, the desired rate shocks seem to play *unimportant* roles.

Perhaps we are also interested to see how the home rate moves in response to a base rate shock. Impulse responses of the home and base interest rates to an innovation in the base rate in the three-variable model are presented in Figure 4.11.[60] These indicate that clearly China, Malaysia, and Japan are the most independent. The rest of the countries may also be considered on the independent side as their initial responses are not as large as the original shock, but there is a tendency to follow the base rate more closely afterwards (although there are large confidence intervals). The most dependent country again appears to be Hong Kong.

4.4.3 Comparison with Other Studies

Various studies have examined the extent of monetary independence in Asian countries. Similarly to our paper, Ma and McCauley (2008) and Kohli (2012) use the NDF market to identify capital controls for China and India respectively. Their results show that indeed the two countries had large capital controls over the 2000s sample period. Ma and McCauley (2008) also test if capital controls enhanced monetary independence by noting that the Chinese exchange rate had been fixed to the dollar until 2005. Because of the fixed exchange regime, in theory the interest rate differential between the Chinese rate and the U.S. rate should be the same when there are no capital controls but the authors see that there is a substantial difference thus indicating that the capital controls are allowing monetary independence in China. This indicates that

[59] If it is ordered third the overall effect is a slight decrease in the Taylor rule shock but not enough to change the overall interpretation of the results. There is almost no change at the 3 month horizon, and there is only a few percentage point differences for most countries after the three year mark.
[60] The results are almost identical to the two variable VAR.

the capital controls were significant in helping China achieve monetary independence. The authors also have results that show the interest differential decreasing over time. We also see in Figure 4.1 that indeed the interest rate differential (the dark blue curve) has decreased in absolute value since 1999 and was close to 0 between 2002 and 2005.[61]

Kim and Lee (2008) also focus on testing monetary independence in East Asian countries from 1987-2002. They adopt a similar regression to eq. (2) however it is in first differences and also contains a lagged dependent variable. Because the sample includes the Asian financial crisis, some countries experience structural breaks and different regimes. Korea and Thailand had followed the U.S. base rate more closely before the crisis than after the crisis. Their results also indicate that Hong Kong and the Philippines appear to be monetarily dependent throughout the sample. On the other hand Malaysia, Japan, Singapore, and Indonesia have insignificant coefficients throughout the period and can therefore be considered independent. The authors argue that even though Malaysia had a period of fixed exchange rates after the crisis, its strong capital controls allowed it to be monetarily independent, but no formal testing is done. Overall our monetary independence results are more or less in line with these.

4.5 Concluding Remarks

In this paper we studied the trilemma in the context of Asian countries. The advantage of our approach is that it allows us to look at specific countries in detail and determine how their capital controls and exchange rate flexibility influence their monetary independence. The baseline results in Table 4.5 indicate that the most monetarily independent countries (based on the U.S. interest rate) either have high capital controls (China) or high exchange rate flexibility (Japan) or some combination of both (Malaysia, India, and Indonesia). The least monetarily independent countries have lower exchange rate flexibility and capital controls (Korea and Singapore). Hong Kong,

[61] In a closer look, it looks as if China just wanted to have a stable interest rate during this period while it was the U.S. that was actually changing its interest rate.

the most dependent country has the lowest exchange flexibility and capital controls – this is because it officially has a currency board with the dollar and free capital mobility. Overall our paper is in support of the trilemma hypothesis.

Further, as the world has become more integrated, economies have desires for similar monetary policies. We thus modify the existing monetary independence measure to include a desired interest rate component (based on the Taylor rule). First we incorporate the desired interest rate into the monetary independence regression for each country. In the regressions the most significant result is that Indonesia is strongly identified as monetarily independent. Further, we use a VAR to argue causality and to see how well the results hold up in the shorter run. The results show several countries that may be heavily exposed to the base interest rate shocks may have paid close attention to their inflation and business conditions in their monetary policy making. In particular, the variance decompositions show that taking into account the desired interest rate makes the most dependent countries - Korea, Singapore, and Hong Kong appear more monetarily independent. This suggests that these countries have greater degree of monetary independence than what the conventional tests may implicate.

Besides the empirical portion, an important contribution of this paper is in its approach in measuring the trilemma components. In particular, we are able to provide de facto measures of capital controls and exchange rate flexibility based on the covered interest rate parity condition. De facto measures on capital controls have also been constructed on China from Ma et al (2008) but they do not emphasize our measure of exchange rate flexibility. Interest rate parity has also been used to argue the trilemma in the past, but in practice authors only use it to form a measure of monetary independence.[62] On the other hand various measures for capital controls and exchange rate flexibility have been used in the literature but they are only weakly based on this theory. The key to our paper is that we use the less risky non-deliverable forward market data (where available) to compute the trilemma components; these are

[62] For example see Klein and Shambaugh (2015).

expected changes in exchange rates (the forward premium) and capital controls (taken as deviations from CIP). Comparing the capital controls with the existing de jure measures of capital controls also suggests there is validity in our results. To obtain the trilemma measures we then simply take the variation of these overtime. The variation of the interest rate differential could perhaps also be used as a monetary independence measure.

Recently there has been a dilemma-trilemma debate. Rey (2015) notes that since the 1990s the world has become more financially integrated and the paper shows evidence that capital flows are highly correlated across countries. Further, the author argues that because of global financial cycles, countries may obtain monetary independence only by imposing capital controls regardless of their exchange rate regime. In a recent note, Klein and Shambaugh (2013) argues against Rey (2015) and provides evidence of the trilemma using the traditional methodology stated in the introduction. Our results also tend to support the trilemma hypothesis. As we can see from the results in Table 4.5, all countries except China rely on exchange flexibility more than capital controls. An extreme case is Japan which almost purely relies on exchange flexibility. More research is warranted as this study employs a small number of countries from Asia.

Table 4.1 Exchange Rate Regime and Capital Controls 1999-2015

Country	Exchange Rate Regime	SD (exchange rate change)	KAOPEN
China	Managed float	3.88	0.84
Malaysia	Managed float	11.77	0.62
Japan	Free Floating	19.50	0.00
India	Floating	14.14	0.84
Indonesia	Managed float	23.58	0.37
Philippines	Floating	13.42	0.63
Thailand	Floating	12.79	0.69
Korea	Floating	20.43	0.50
Singapore	Managed float	9.44	0.00
Hong Kong	Currency board	0.79	0.00

Note: KAOPEN is Chin-Ito (2008) capital control index, estimation is based on data availability for each country from 1999-2015. See Appendix E.

Table 4.2 Augmented Dicky Fuller Test

	DF	Critical	Values	
	Statistic	1%	5%	10%
USA	-3.484	-3.48	-2.849	-2.568
China	-1.369	-3.485	-2.93	-2.642
Malaysia	-1.417	-3.48	-2.892	-2.607
Japan	-2.707	-3.48	-2.826	-2.546
India	-1.983	-3.48	-2.825	-2.546
Indonesia	-2.863	-3.489	-2.941	-2.653
Philippines	-3.366	-3.494	-2.831	-2.552
Thailand	-2.851	-3.48	-2.826	-2.546
Korea	-2.844	-3.48	-2.838	-2.557
Singapore	-3.224	-3.465	-2.824	-2.545
Hong Kong	-2.753	-3.462	-2.824	-2.545

Table 4.3 Capital Control Announcements

Country	Events
Hong Kong Source: Asia Business council, June 2010	2010, Hong Kong implemented several controls to prevent capital inflows.
India Source: Patnaik and Shah (2012)	2007.8, India implemented a quota on foreign debt and forbid exchange borrowed foreign currencies into Rupee, to regulate huge capital inflow.
Indonesia Sources: Titiheruw and Raymond (2008); Singh (2010)	2001 and 2006, there was restrictions on rupiah transactions and foreign currency loans by the Bank of Indonesia. 2009, Bank Indonesia issued restrictions on short-term capital flows.
Korea Source: IMF's AREAER	2010.6, to manage a huge capital flow, Korea imposed capital controls on currency derivative: local commercial banks' currency derivative products cannot be worth more 50% of the bank's capital; the number is 250% for the local branch of foreign banks. Also impose interest tax on bond investment.
Thailand Source: Feng and Liu (2013)	2003 and after, Thailand implimented controls on inflows to stabilize exchange rate (prevent appreciation). Short-term debt cannot exceed 50 million Thailand Baht per resident. The balance of non-resident's Baht account cannot exceed 0.3 billion. 2006, Thailand imposed controls on inflows. Local banks cannot issue any financial products to non-residents. 2006.12-2008.3 URR: 30% of foreigners' money, that is used for bond investment in Thailand, should be saved with no interest in central bank of Thailand for one year. The money may then be returned to the owner one year later.

Table 4.4 Baseline Regressions

VARIABLES	China	Malaysia	Japan	India	Indonesia	Philippines	Thailand	Korea	Singapore	Hong Kong
Base Rate	0.00948	0.0836***	0.0388***	0.321***	0.980***	1.083***	0.350***	0.577***	0.428***	0.920***
	(0.0286)	(0.0200)	(0.00720)	(0.0554)	(0.119)	(0.102)	(0.0284)	(0.0250)	(0.0159)	(0.0162)
Constant	0.0239***	0.0307***	0.00167***	0.0740***	0.0741***	0.0386***	0.0200***	0.0277***	0.00358***	-0.00903***
	(0.00115)	(0.000528)	(0.000163)	(0.00204)	(0.00248)	(0.00290)	(0.000780)	(0.000677)	(0.000241)	(0.000340)
Observations	179	188	202	201	176	172	200	202	190	197
R-squared	0.001	0.098	0.104	0.122	0.245	0.452	0.489	0.714	0.876	0.948

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4.5 Sample Standard Deviation of Trilemma Components

	China	Malaysia	Japan	India	Indonesia	Philippines	Thailand	Korea	Singapore	Hong Kong
Capital Control	3.97	2.62	0.12	2.32	5.20	2.77	6.81	1.16	1.09	0.19
Forward Premium (Δf)	3.66	3.19	2.05	2.98	6.30	4.49	7.21	1.56	1.79	0.52
Interest Differential	2.31	2.07	2.11	2.39	3.08	2.58	1.62	1.22	1.28	0.50
Changes in exchange rate	3.88	11.77	19.50	14.14	23.58	13.42	12.79	20.43	9.94	0.79
Observations	179	188	202	201	176	172	200	202	190	197

Table 4.6 Regressions with Desired Interest Rate

VARIABLES	China	Malaysia	Japan	India	Indonesia	Philippines	Thailand	Korea	Singapore	Hong Kong
Base Rate	0.0269	0.0849***	0.0216***	0.572***	-0.388***	1.177***	0.401***	0.565***	0.431***	0.892***
	(0.0272)	(0.0276)	(0.00696)	(0.0461)	(0.0860)	(0.148)	(0.0208)	(0.0255)	(0.0158)	(0.0152)
Desired Rate	0.0553***	0.0111	0.0550***	0.278***	0.965***	-0.103	0.0889***	0.0126	-0.0181***	0.00186
	(0.0144)	(0.0287)	(0.00990)	(0.0304)	(0.0373)	(0.104)	(0.00466)	(0.0306)	(0.00442)	(0.00495)
Constant	0.0212***	0.0301***	0.00161***	0.0364***	-.0256***	0.0447***	0.0155***	0.0277***	0.00418***	-0.00726*
	(0.00109)	(0.000954)	(0.000215)	(0.00364)	(0.00377)	(0.00638)	(0.000572)	(0.00175)	(0.000335)	(0.000430)
Observations	179	185	199	198	145	172	174	197	188	188
R-squared	0.039	0.111	0.319	0.392	0.866	0.457	0.757	0.713	0.883	0.951

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4.7 Engle-Granger Cointegration Tests

	Base Rate and Home Rate				Base Rate, Home Rate and Taylor Rate			
	statistic	1% Critical	5% Critical	10% Critical	statistic	1% Critical	5% Critical	10% Critical
China	-1.21	-3.959	-3.371	-3.068	-1.242	-4.376	-3.789	-3.5
Malaysia	-1.411	-3.956	-3.369	-3.067	-1.253	-4.373	-3.788	-3.5
Japan	-1.5	-3.951	-3.367	-3.066	-1.345	-4.367	-3.784	-3.5
India	-1.188	-3.952	-3.367	-3.066	-1.999	-4.368	-3.784	-3.5
Indonesia	-1.482	-3.96	-3.371	-3.069	-2.39	-4.396	-3.801	-3.5
Philippines	-2.271	-3.961	-3.372	-3.069	-3.14	-4.379	-3.791	-3.5
Thailand	-1.474	-3.952	-3.367	-3.066	-2.282	-4.378	-3.791	-3.5
Korea	-1.856	-3.951	-3.367	-3.066	-1.955	-4.368	-3.785	-3.5
Singapore	-2.452	-3.955	-3.369	-3.067	-2.722	-4.372	-3.787	-3.5
Hong Kong	-3.566	-3.953	-3.367	-3.066	-3.05	-4.372	-3.787	-3.5

Table 4.8 VAR Variance Decompositions of Home Rate

	Original		with Desired Rate		
	Base rate Shocks	Home rate Shocks	Base rate Shocks	Desired rate Shocks	Home rate Shocks
China					
3 month	0.9	99.1	0.8	0.4	98.8
3 year	2.3	97.7	2.6	2.7	94.7
Malaysia					
3 month	0.5	99.5	0.3	3.2	96.6
3 year	3.7	96.3	5.5	18.6	75.8
Japan					
3 month	24.7	75.3	23.9	1.9	74.2
3 year	42.2	57.8	41.3	16.0	42.7
India					
3 month	6.3	93.7	6.6	0	93.4
3 year	15.5	84.5	18.8	26.2	55.0
Indonesia					
3 month	2.5	97.5	3.8	.3	95.9
3 year	21.5	78.5	32.7	3.5	63.8
Philippines					
3 month	1.0	99.0	1.1	1.0	97.8
3 year	40.1	59.9	39.6	10.7	49.7
Thailand					
3 month	27.2	72.8	37.1	6.3	56.6
3 year	46.6	53.4	45.2	27.0	27.8
Korea					
3 month	24.3	75.7	22.1	11.3	66.6
3 year	66.8	33.2	41.3	28.1	30.6
Singapore					
3 month	41.6	58.4	37.5	0.4	62.1
3 year	58.3	41.7	38.7	22.6	38.7
Hong Kong					
3 month	72.3	27.7	70.2	0.4	29.5
3 year	94.0	6.0	74.3	17.7	8.1

Figure 4.1 China

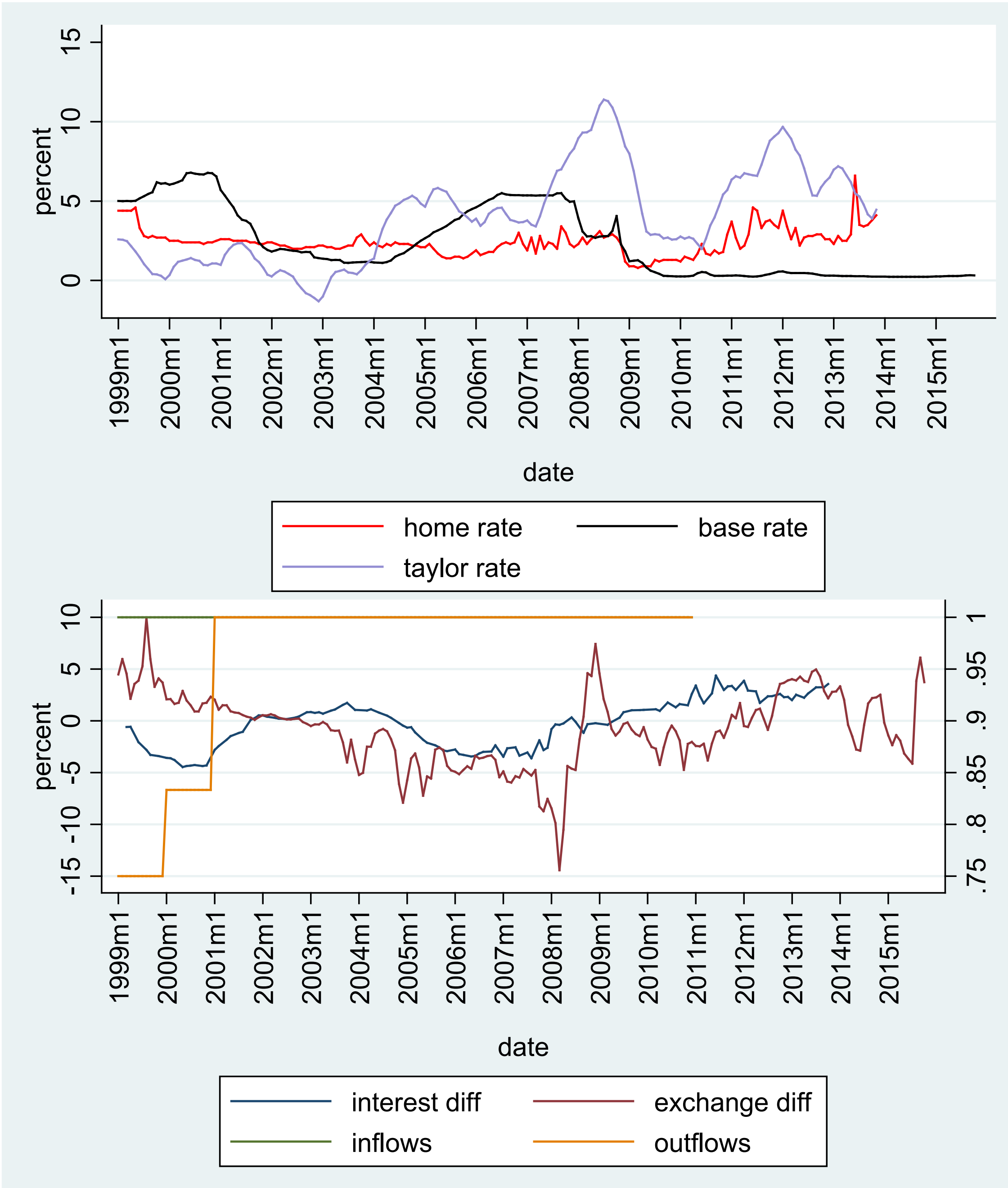


Figure 4.2 Malaysia

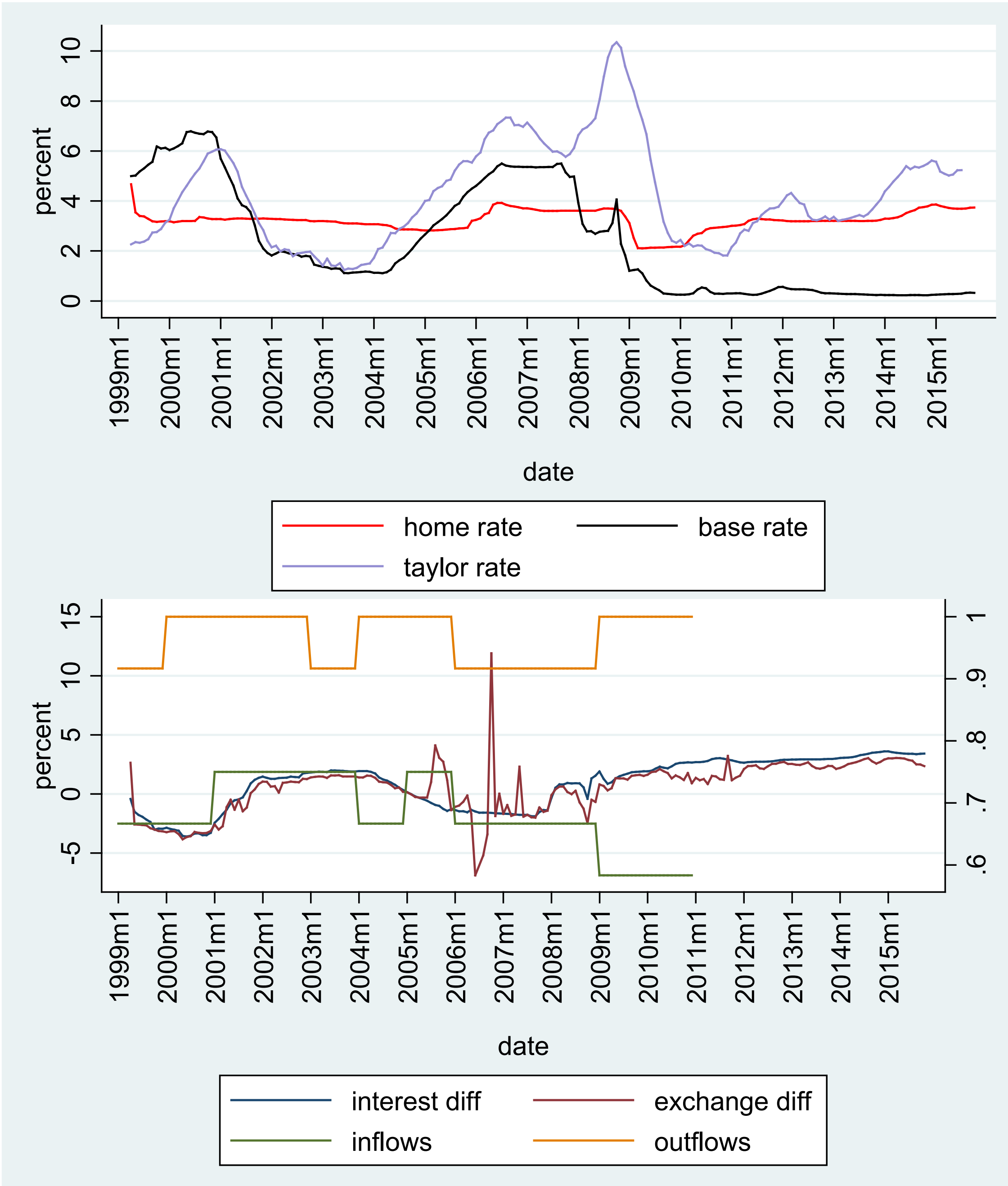


Figure 4.3 Japan

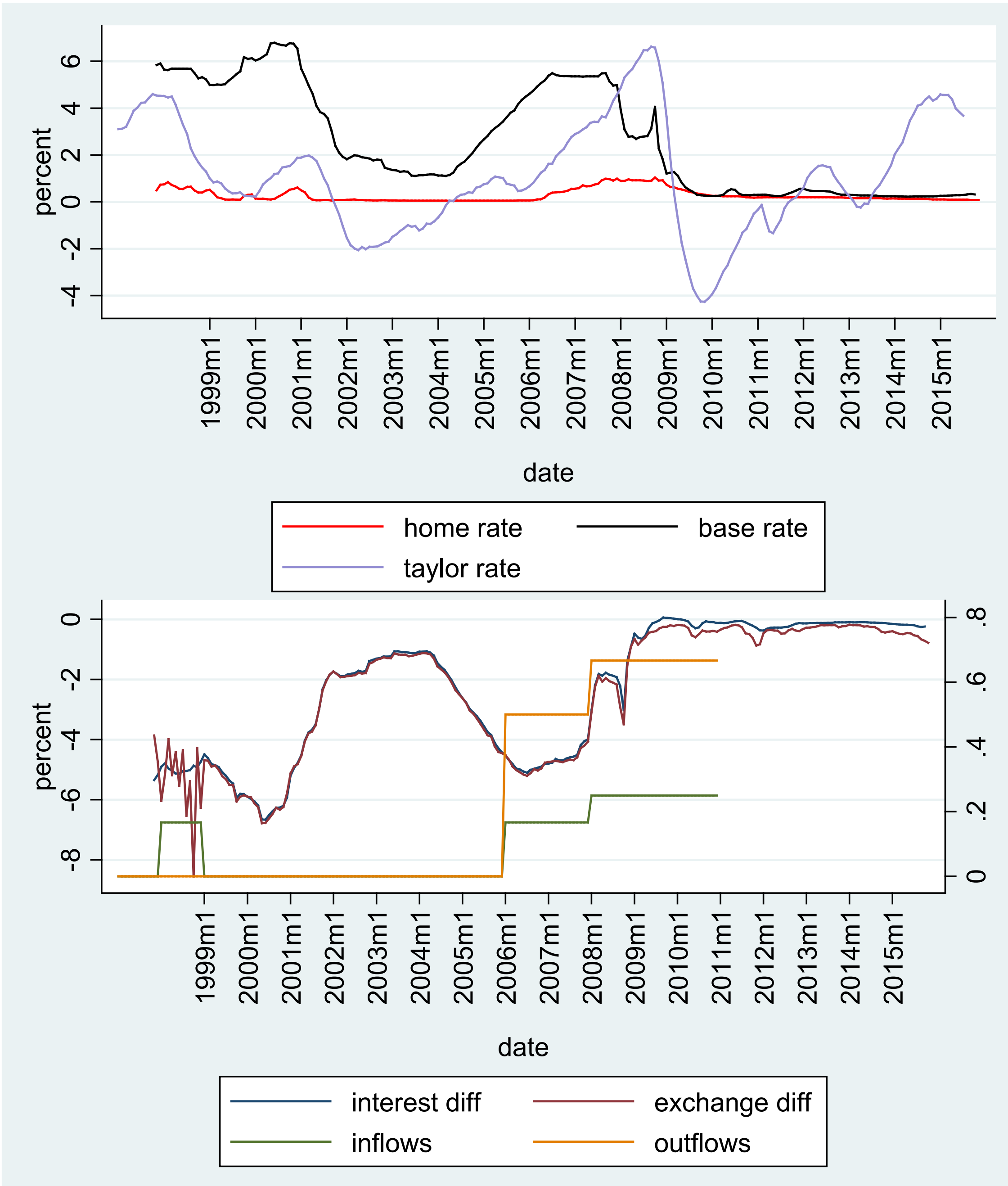


Figure 4.4 India

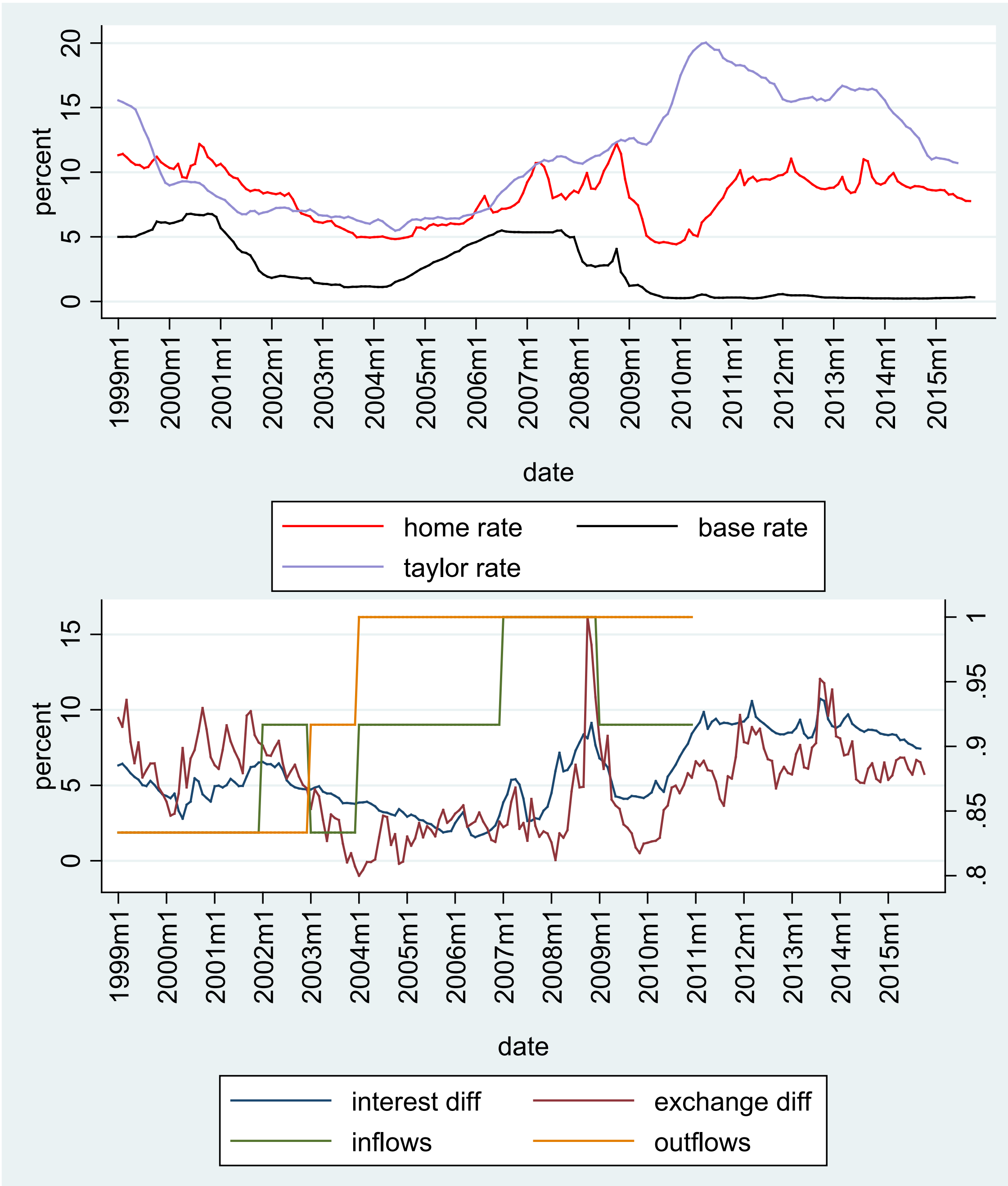


Figure 4.5 Indonesia

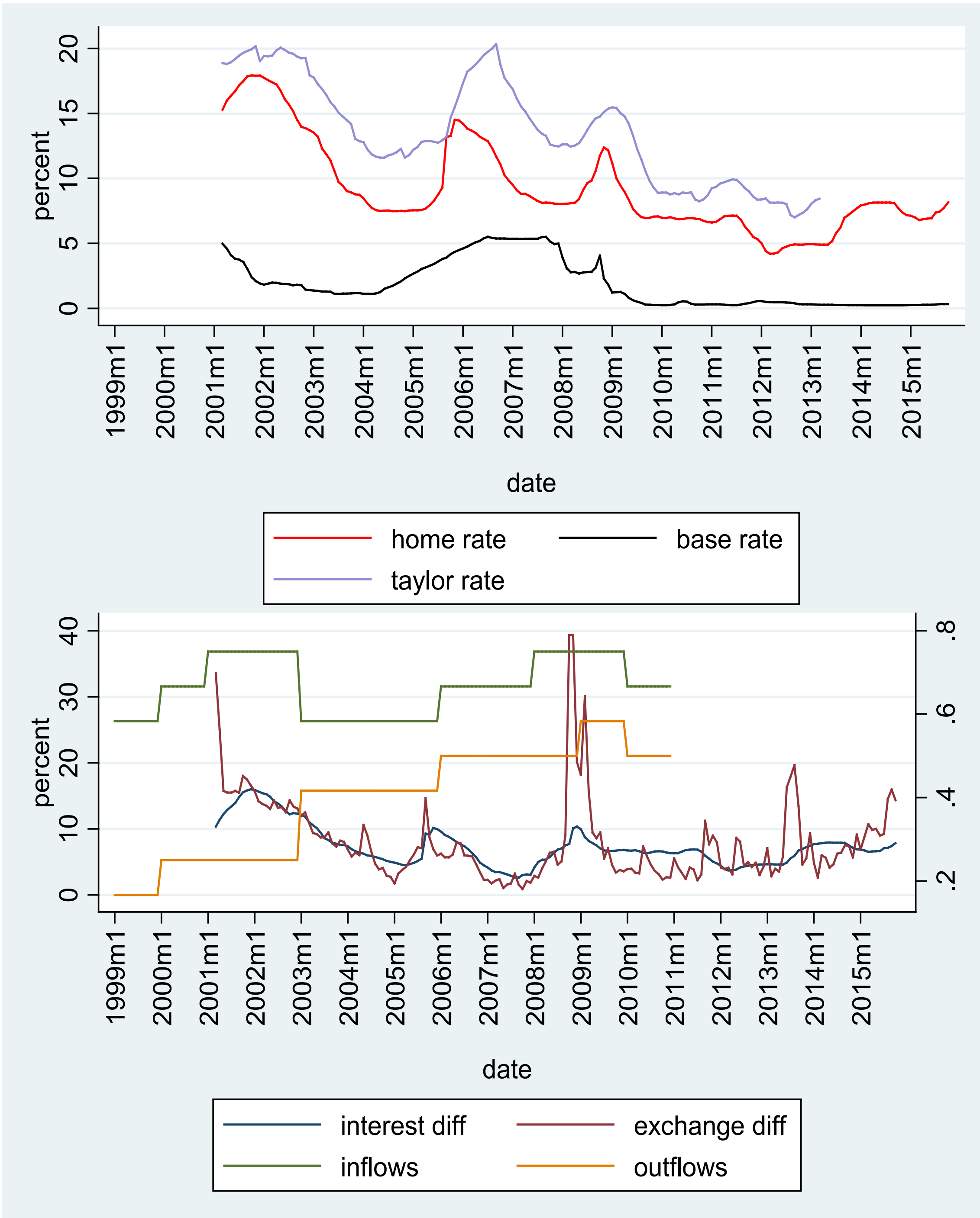


Figure 4.6 Philippines

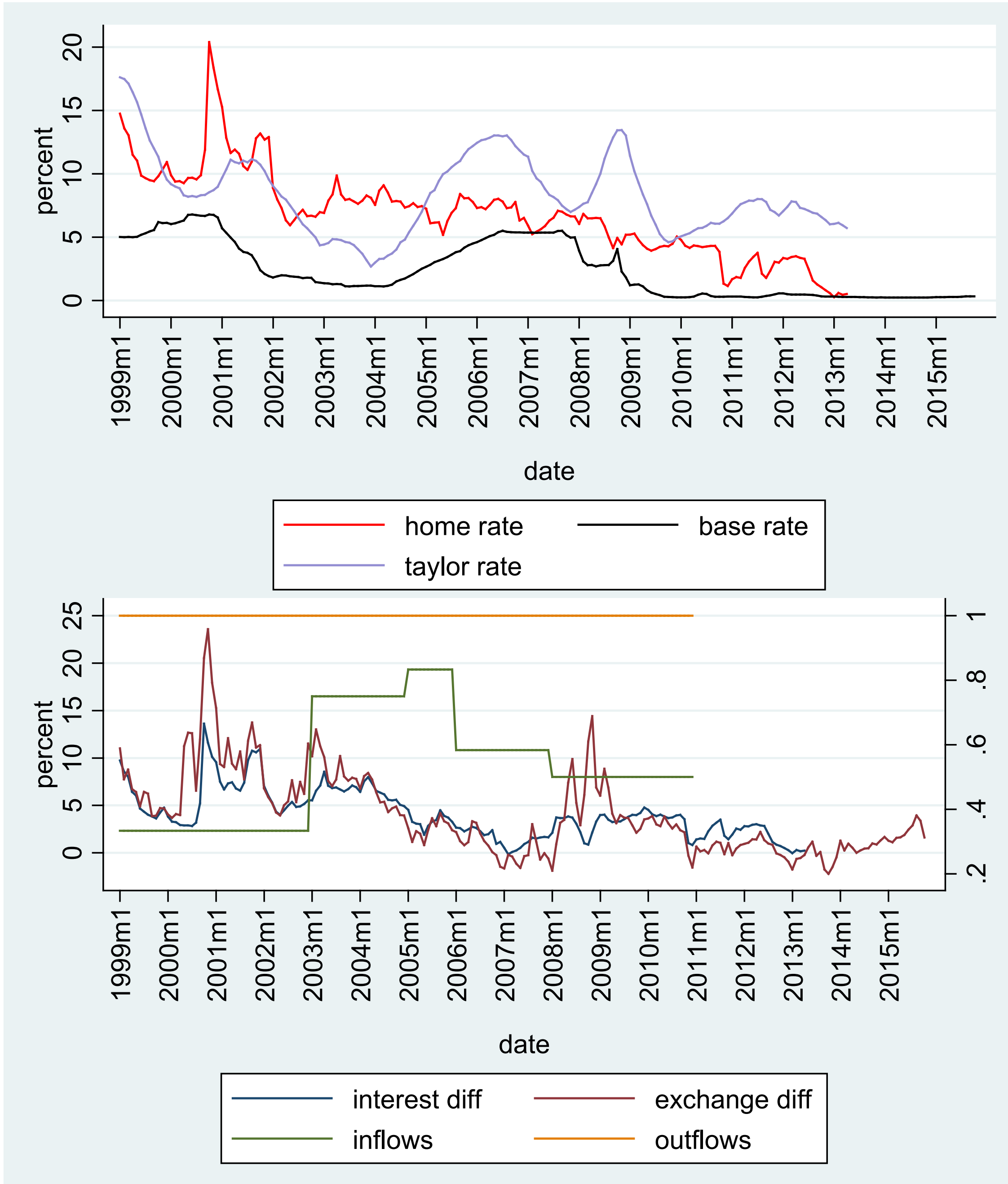


Figure 4.7 Thailand

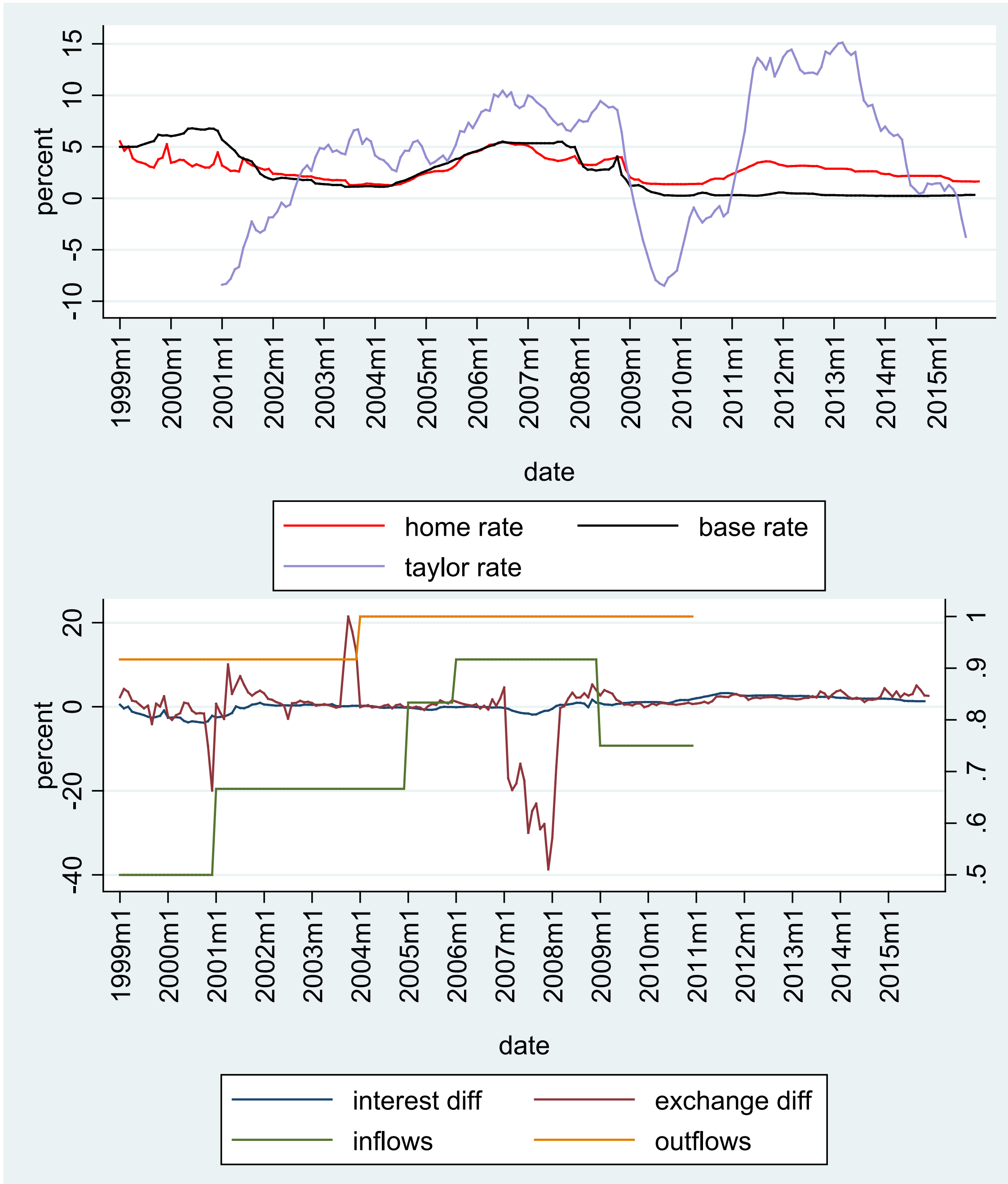


Figure 4.8 Korea

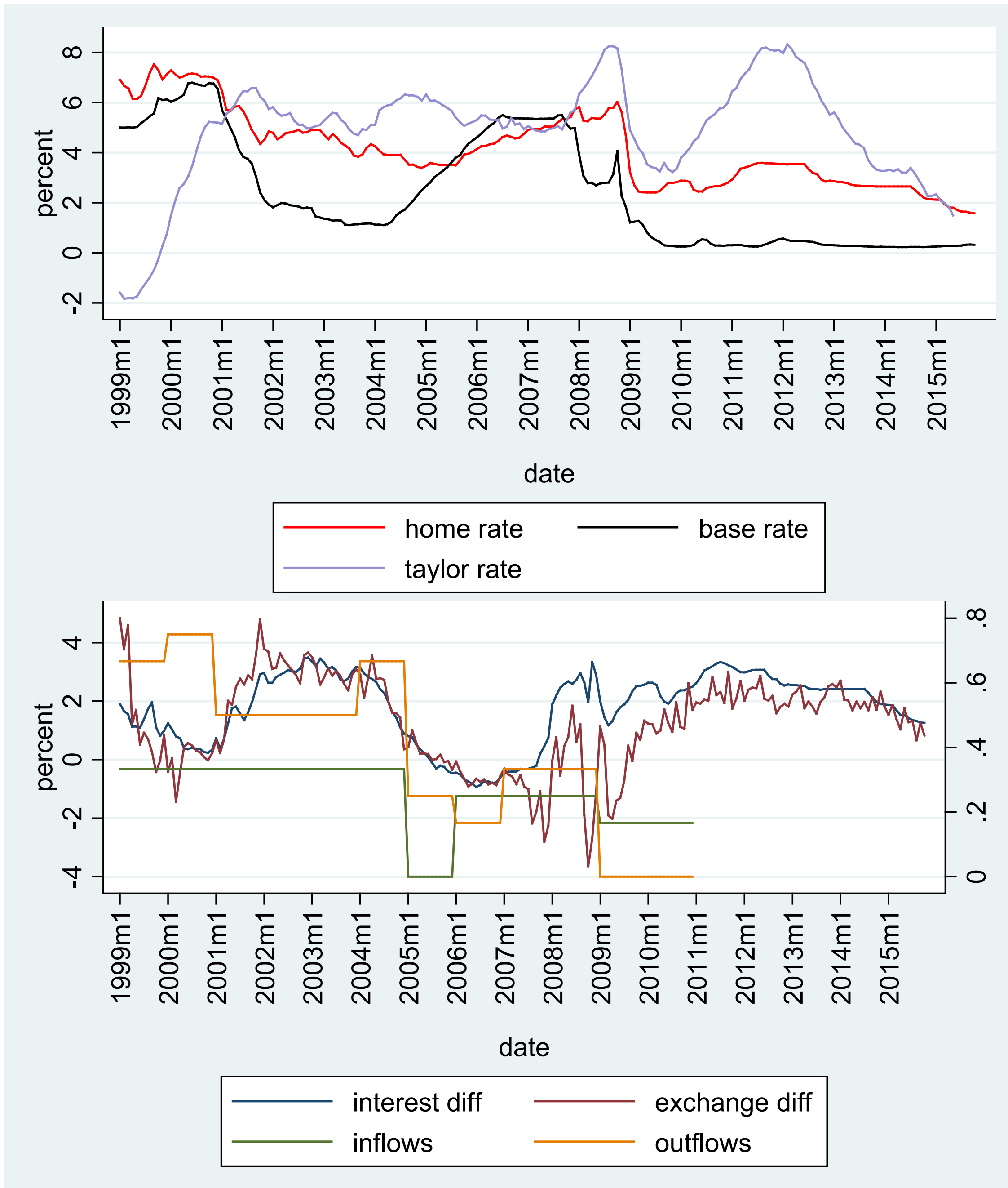
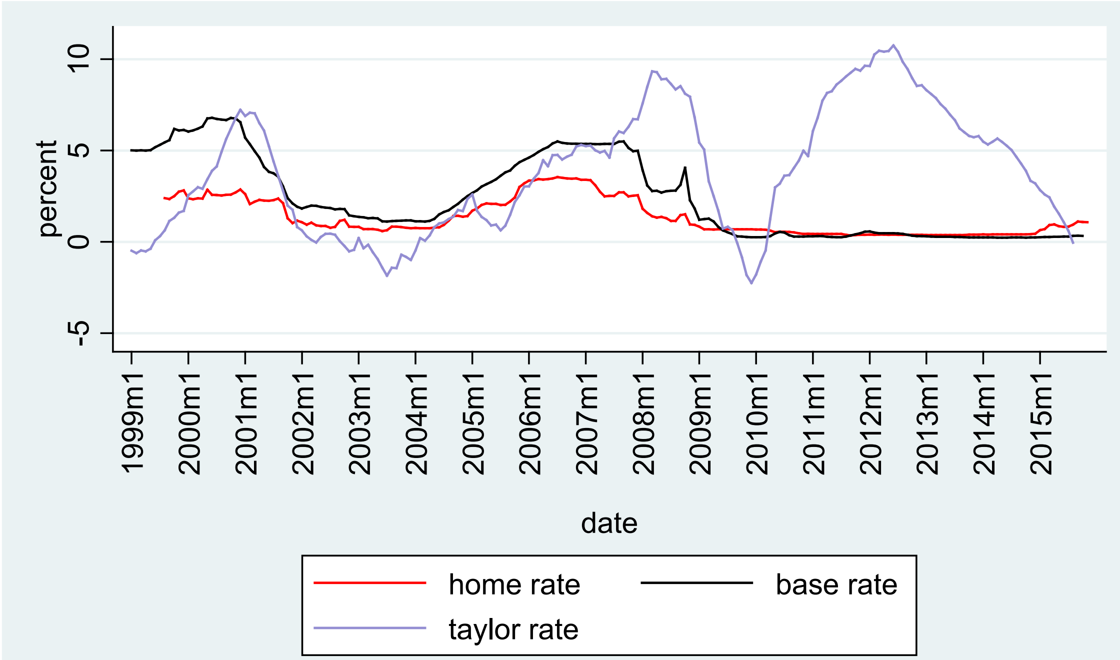


Figure 4.9 Singapore



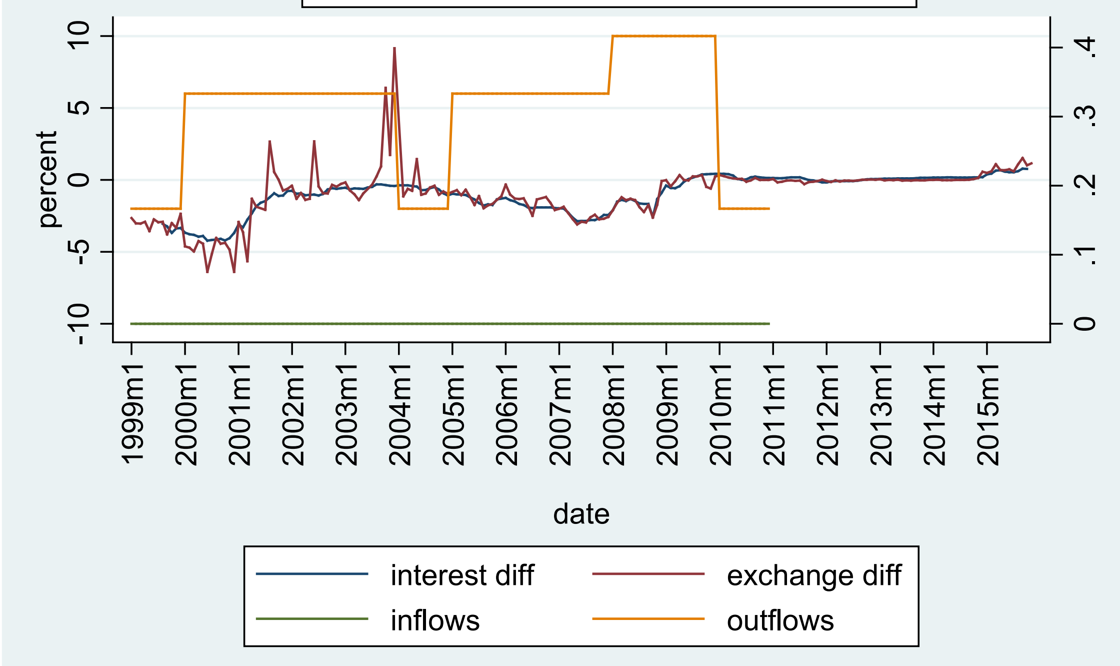


Figure 4.10 Korea

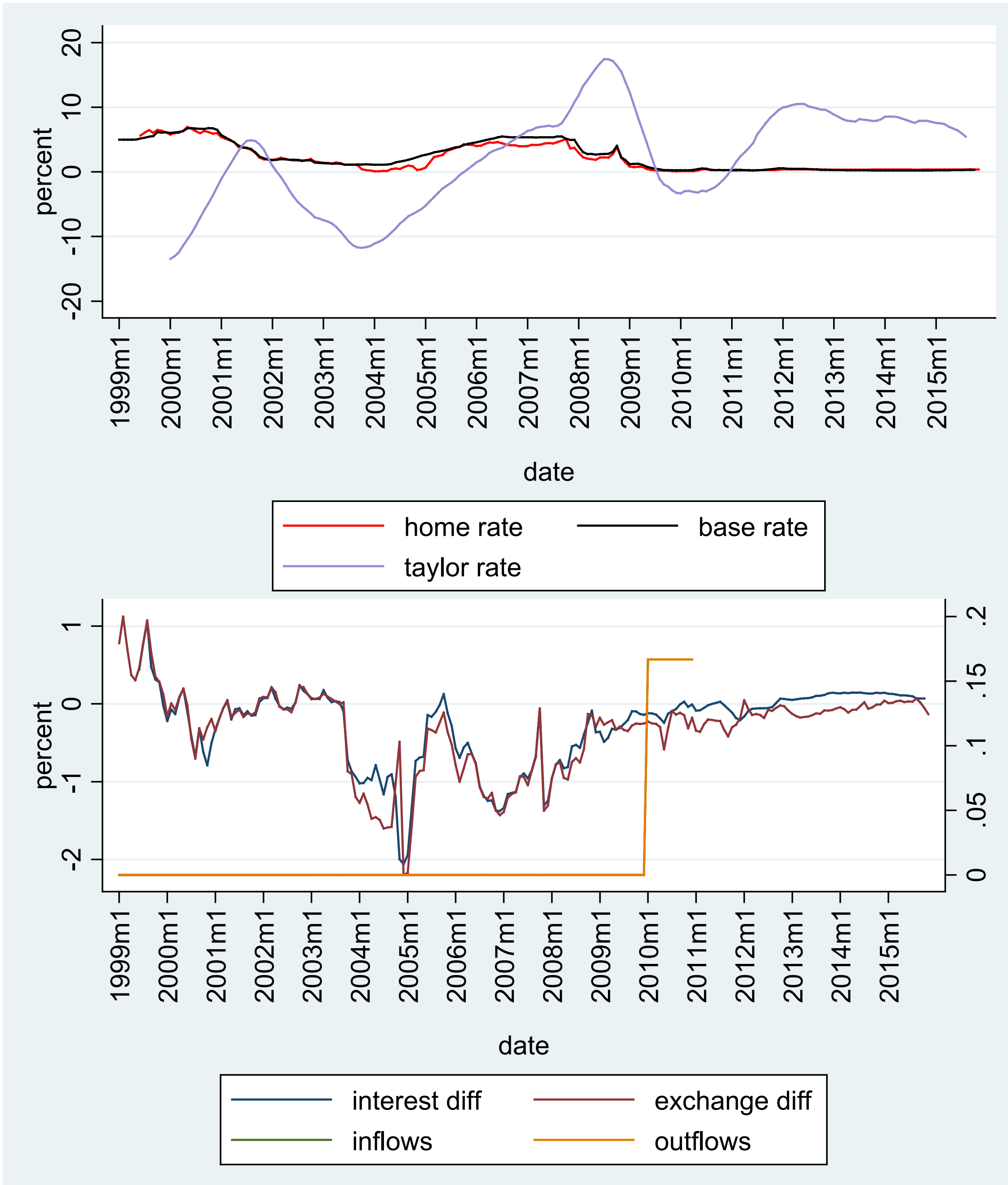
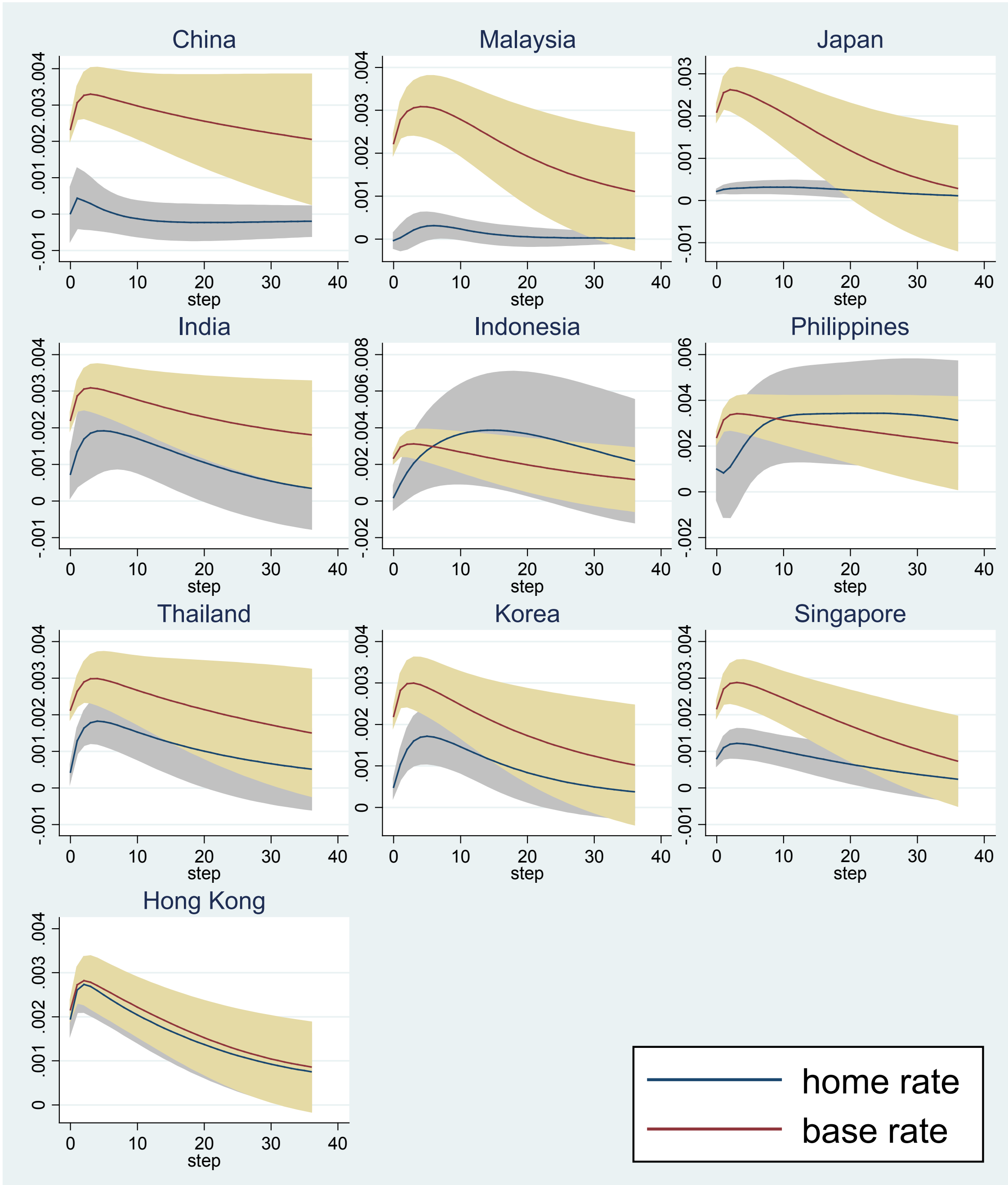


Figure 4.11 VAR



Appendices

Appendix A: Data

Data on the value of bilateral exports comes from IMF – Direction of Trade Statistics. The DOT reports data on both exports and imports. To obtain this value, both sets of data are used in that the average of j's imports from i and the exports to j from i is taken. Over a fifth of observations have values missing for either of the two in which case only the non-missing value is used for exports.

Data on GDP, exchange rates (used to convert into U.S. dollars), the U.S. GDP deflator (used to convert into real values), population (used for gdp/capita), oil price (Brent Crude), and the real effective exchange rate, all come from IMF – International Financial Statistics. Following Glick and Rose (2002) the GDP data is supplemented using the World Bank's World Development Indicators.

The price of oil varies depending on its grade and location. Brent Crude is high grade oil found in the North Sea. It is used as an international benchmark as to how world oil prices behave. The oil price is average annual "spot" Dated Brent crude oil price.

Data on Free Trade Agreements comes from Frankel (2010), and The World Bank – global preferential trade agreements database.

The distance is calculated using latitude and longitude coordinates of the geographic center of the countries as defined by the CIA – The World Factbook. The alternative measure of distance is calculated using the coordinates of the capitals of the countries, which are also obtained from The World Factbook. Stata's globdist command is used to calculate the great circle distance between any two sets of coordinates.

For the additional oil price measures: The West Texas Intermediate comes from the Federal Reserve Bank of St. Louis (http://research.stlouisfed.org/fred2/data/OILPRICE.txt), and the Dubai Fateh from the World Bank – GEM Commodities.

Appendix B: Selected Country Sample

Industrialized Countries

Australia	Greece	New Zealand
Austria	Hong Kong	Norway
Belgium	Ireland	Portugal
Belgium-Luxembourg	Israel	Singapore
Canada	Italy	Spain
Denmark	Japan	Sweden
Finland	South Korea	Switzerland
France	Luxembourg	United States
Germany	Netherlands	United Kingdom

Additional Countries

Algeria	Kuwait	Thailand
Argentina	Malaysia	Turkey
Bangladesh	Mexico	Ukraine
Brazil	Nigeria	United Arab Emirates
Bulgaria	Pakistan	Venezuela
Chile	Peru	Vietnam
China	Philippines	
Colombia	Poland	Former countries
Czech Republic	Russia	Czechoslovakia
India	Saudi Arabia	Eastern Germany
Indonesia	Slovakia	U.S.S.R.
Iran	South Africa	Yugoslavia, SFR

Appendix C: The AvW Model

The AvW (2003) model is technically just a simple general equilibrium model of world trade. The model assumes that each country produces 1 good – a unique product. Each country is also a representative consumer and has a CES preference function that includes every country's good including its own. For each country j the utility can be expressed as:

$$(1c) \qquad U_j = \left(\sum_i \beta_i^{\frac{1-\sigma}{\sigma}} c_{ij}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

Where: c_{ij} represents j's consumed quantity of country $i's$ good. The summation is over all countries, which implies that c_{jj} is the own good consumption of j. It is assumed that goods are treated as substitutes rather than compliments in which case $\sigma > 1$. β_i is an additional preference parameter that is specific to country $i's$ good and is the same for all countries. In particular, the higher the β_i the less valuable the $i'th$ good is to the other countries.

In order to consume the goods, each country has to buy them. Let p_{ij} be the price that country j pays for good i. Prices of good i will differ across countries depending on the trade costs between countries i and j. These may include shipping, tariffs, and others. Let p_i be the production price of good i in country i. Assume that the destination price in j is higher by a factor of t_{ij} – the trade cost. Then $p_{ij} = p_i t_{ij}$. There are also internal trade costs where: $p_{ii} = p_i t_{ii}$. Here, t_{ii} is assumed to be the trade cost factor within the country (the internal trade cost). Generally, the local good is not bought directly from the factory, and so t_{ii} can be seen to include the additional cost of transportation and taxes that are paid. t_{ii} is likely to differ across countries. If one assumes that production takes place in 1 location, then a larger country will likely have a higher t_{ii}.

From the definitions above, $p_{ij}c_{ij} = p_i t_{ij} c_{ij}$ is the total value of goods bought from i by j. This can also be viewed as value of exports from i to j, or value internal consumption for $p_j t_{jj} c_{jj}$. Country j chooses how much of the goods to buy and is constrained by its GDP. In this case, the budget constraint for country j is:

$$(2c) \qquad \sum_i p_i t_{ij} c_{ij} \le Y_j$$

On the other hand, GDPs are just the sum of the values of what is exported and what is used for internal consumption. In this case for country i this is:

$$(3c) \qquad \sum_j p_i t_{ij} c_{ij} = Y_i$$

Maximizing $(1c)$ subject to $(2c)$ implies that:

$$(4c) \qquad T_{ij} = p_i t_{ij} c_{ij} = \frac{Y_j (p_i t_{ij} \beta_i)^{1-\sigma}}{\sum_i (p_i t_{ij} \beta_i)^{1-\sigma}}$$

In this model the GDPs (Y), the trade costs (t), and σ are assumed exogenous, and the prices (p) (and quantities (c)) are assumed endogenous. Ultimately, one is interested in solving for the value of exports from i to j (T_{ij}) given these exogenous variables. The equations above are defined for all countries and so this can be done using (3c) and (4c), along with a particular standard /normalization of the prices[63].

To be consistent with AvW define:

$$(5c) \qquad P_j = \left(\sum_i (p_i t_{ij} \beta_i)^{1-\sigma} \right)^{1/(1-\sigma)}$$

Then replacing (4c) into (3c)

obtain: $\sum_j \frac{Y_j (p_i t_{ij} \beta_i)^{1-\sigma}}{P_j^{1-\sigma}} = Y_i$. Define:

$$(6c) \quad \Pi_i = \left(\sum_j \frac{Y_j {t_{ij}}^{1-\sigma}}{P_j^{1-\sigma}} \right)^{1/(1-\sigma)} \qquad \forall i$$

Then $(p_i \beta_i)^{1-\sigma} = Y_i / \Pi_j^{1-\sigma}$ and plugging back in $(4c)$ implies

$$(7c) \qquad T_{ij} = \frac{Y_i Y_j {t_{ij}}^{1-\sigma}}{P_j^{1-\sigma} \Pi_i^{1-\sigma}}$$

Π_i is known as the exporter resistance to trade, while P_j is the importer resistance to trade.

Now instead of solving for the prices, it is easier to solve for $\Pi_j^{1-\sigma}$, $and\ P_i^{1-\sigma}$. Plugging in $(p_i \beta_i)^{1-\sigma} \ = Y_i / \Pi_j^{1-\sigma}$ into (5c) implies:

$$(8c) \quad P_j = \left(\sum_i \frac{Y_i {t_{ij}}^{1-\sigma}}{\Pi_i^{1-\sigma}} \right)^{1/(1-\sigma)} \qquad \forall j$$

When trade costs are symmetric, i.e. $t_{ij} = t_{ji}$, then the unique solution to $(6c)\ and\ (8c)$ is $P_j = \Pi_j$. As stated in AvW this implies a particular normalization of the prices. Then using either $(6c)$ (or $(8c)$) one can solve for the Ps given values for the

[63] Intuitively, a normalization is required because the total value of GDPs is known but quantities and prices are not. Therefore, prices are only solvable up to a ratio without a normalization. The solution for T_{ij} will be exactly the same given any normalization.

trade costs, gdps, and sigma. In section 2.5, the gravity equation (6) additionally multiplies the numerator and denominator by world GDP. Therefore the P_j in (6) also has a world GDP in its denominator.

Theoretical Predictions of Oil Price Impact

Unlike the traditional gravity equation, the GE gravity equation also contains the multilateral resistance terms. As these terms vary by country and are a function of trade costs and GDPs, the effect of oil prices on trade will not only vary by distance, but will also vary by country pair. To see this more clearly, consider the trade cost function to be: $t_{ij} = e^{gx_{ij}} * x_{ij} * other_{ij}$[64] $\forall i, j$. Where $e^{gx_{ij}}$ is an interaction variable, and $other_{ij}$ are other trade costs independent from oil prices. Now taking the derivative of the log of eq. (6) w.r.t. oil price, and assume no change to GDPs ⇒

$$(9c) \quad \frac{dlnT_{ij}}{dg} = (\sigma - 1)\left(\frac{dlnP_i}{dP_i}\frac{dP_i}{dg} + \frac{dlnP_j}{dP_j}\frac{dP_j}{dg} - \frac{dlne^{gx_{ij}}}{dg}\right)$$

To predict how trade will change, it is important to solve for $\frac{dP_i}{dg}$, and $\frac{dP_j}{dg}$. To do this take the total differential of eq. (7) ⟹

$$0 = \frac{-dF}{dP_j}dP_j + \sum_i \left(\frac{dF}{dP_j}dP_i + \frac{dF}{dg}dg + \frac{dF}{d\theta_i}d\theta_i + \frac{dF}{dx_{ij}}dx_{ij} + \frac{dF}{dother_{ij}}dother_{ij}\right) \quad \forall j$$

Following AvW, $\frac{dP_i}{dg}$, and $\frac{dP_j}{dg}$ can easily be solved when the model is at the frictionless equilibrium[65]. So assume that $x_{ij} * other_{ij} = 1 \ \forall i, j \ and \ g = 0 \Longrightarrow P_j, P_i = 1$. Further, I am assuming that only oil prices, and therefore multilateral resistances change. In this case $dother_{ij} = dx_{ij} = d\theta_i = 0$. Then:

$$(10c) \quad 0 = -(1-\sigma)dP_j + \sum_i \left((\sigma-1)\theta_i dP_i + (1-\sigma)\theta_i x_{ij} dg\right) \quad \forall j$$

Dividing by $(1-\sigma)$, multiplying by θ_j, summing over all j, and using the fact that $\sum_j \theta_j = 0 \Longrightarrow$

[64] Here it is not necessary to multiply by g – the main effect of oil price. As mentioned in footnote 1, a change in the "overall" trade costs (such as a multiplication by a constant for every country-pair during the same period) does not change the behavior of trade. All that matters for this model is how the trade costs relate to each other and multiplying them all by some factor will not change this relationship.

[65] The frictionless equilibrium assumes that trade costs are the same everywhere; then trade between countries is solely determined by their GDPs. In this case all trade costs are set to equal 1.

$$(11c) \quad 0 = -2\sum_j \theta_j dP_j + \sum_j \sum_i \theta_j \theta_i x_{ij} dg \quad \forall j$$

(11c) into (10c) implies

$$(12c) \quad \frac{dP_j}{dg} = -\sum_j \sum_i \theta_j \theta_i x_{ij}/2 + \sum_i \theta_i x_{ij} \quad \forall j$$

(12c) into (9c) implies

$$(13c)^{66} \quad \frac{dlnT_{ij}}{dg} = (\sigma - 1)\left(-\sum_j \sum_i \theta_j \theta_i x_{ij} + \sum_i \theta_i x_{ij} + \sum_j \theta_j x_{ji} - x_{ij}\right) \quad \forall i, j$$

In the traditional gravity model, $\frac{dlnT_{ij}}{dg}$ depended on just the distance between the two countries and the level of oil price. For that model, neither the economic size of the countries nor their world location mattered as to how trade decreased. However, it is clearly seen from (13c) that the higher the country specific terms: $\sum_i \theta_i x_{ij} + \sum_j \theta_j x_{ji}$, the less decrease in trade there will be. In particular, the change in trade will also depend on the GDPs of the two countries and their distances to the rest of the world.

To see how the change in trade depends on GDPs, first consider internal distances (x_{ii}) to be small relative to distances across countries (x_{ij}). Then as seen from (13c), $\sum_i \theta_i x_{ij} + \sum_j \theta_j x_{ji}$ will be smaller the larger (GDP wise) the countries' trading. This means that given the same distance, two countries with larger GDP shares (θ_is) will have their trade decrease by more relative to two countries with smaller GDP shares. This is the same conclusion as AvW (p.176). From looking at eq. (6), the logic here is that countries with very large GDPs have high internal consumptions (T_{ii}) relative to their GDP. When oil prices increase, T_{ii} will only increase by a small percentage in order to soak up the loss international trade (T_{ij}). Therefore, $P_i^{\sigma-1}$ will not increase by a large factor and international trade will decrease by a larger percentage for these larger countries. Alternatively, consider an extreme case where country i has 99% of world GDP, then clearly after an oil price increase, T_{ii} will not increase by a large factor (as that will imply $T_{ii} > Y_i$). Therefore, $P_i^{\sigma-1}$ will only increase a by a small percentage relative to all other $P_j^{\sigma-1}$.

On the other hand, consider the role location plays. First it can be seen that the term $-x_{ij}\ \forall i, j$ in (13c) implies that an increase in the oil price will decrease trade by more for the greater distance. This is the same conclusion as in the traditional gravity model. However, the GE model also has the additional MR terms. This implies that there will be *additional* trade changes depending on the location of the countries with the rest

[66] The same results are obtained from the approximation by Baier and Bergstrand (2009), due to their approximation also being around the frictionless equilibrium.

of the world. Consider two countries at a set distance apart. If the two countries in question are very isolated, then $\sum_i \theta_i x_{ij} + \sum_j \theta_j x_{ji}$ will be high and their trade will not decrease as much as if they were not as isolated. The logic behind this is that if they are not isolated, they can easily divert trade to the many countries close to them. However, if they are isolated they will not be able to divert trade as easily and mainly just increase internal trade / consumption of own good.

This additional trade effect, however, is evaluated starting at a frictionless equilibrium. In reality, the system could be far from this equilibrium. It is likely that the more isolated the country, the greater the trade costs and therefore the greater the MR. When there is an oil price increase the already high MR will not increase much further[67]. Therefore, this mitigates the previous result, and the two results might actually counteract each other so that there will be no difference regarding the role of location. This implies that conclusions about additional trade changes based on isolation cannot be made from the above analysis.

[67] Suppose country i is very isolated, this is a case similar to country i having a large GDP. Then its MR (P_i) is very high and if t_{ii} is reasonably low, this implies that internal trade (T_{ii}) will be high and its international trade (T_{ij}) will be low. When there is an increase in trade costs (t_{ij}), international trade will fall. Because international trade is low to begin with, internal consumption is high and only a small percent increase in it will be enough to soak up the fall in international trade. Therefore, there will only be a slight increase in P_i.

Appendix D: GE Proof

Proposition: *For the three step process in determining the general equilibrium impact of a policy, it does not matter what the internal trade costs are set to - in the end the counterfactual trade level will be the same.*

Here the strategy is to use two different sets of internal trade costs and to show that they lead to the same counterfactual trade level using the 3 step procedure from section 2.5.

The first step is to obtain the MRs and trade costs using each of the of the two different internal trade costs. Let the first set of internal trade costs be $\{t_{ii}^{1-\sigma}\}\ \forall i.$ Let the alternative be denoted with a star subscript $\{t_{*ii}^{1-\sigma}\}\ \forall i$. Let all results associated with the alternative also be denoted with a star subscript. Now suppose that the relationship between the two different trade costs is $t_{ii}^{1-\sigma} = k_i t_{*ii}^{1-\sigma}\ \forall i$ where k_i is just the number that will make the equation hold. Then using (6) one can calculate the MRs and the other (international) trade costs given the internal trade costs, the given trade levels, and the GDPs. For the first set of internal trade costs, let the calculated MRs be $\{P_i^{1-\sigma}\}\ \forall i$, and the calculated international trade costs be $\{t_{ij}^{1-\sigma}\}\ \forall i,j \quad i \neq j$. Then for the second set of internal trade costs the calculated international trade costs, and MRs will be $\{t_{*ij}^{1-\sigma}\}$, $\{P_{*i}^{1-\sigma}\}$. As the internal trade equations in (6) are used to solve for the MRs, it can easily be seen that $P_{*i}^{1-\sigma} = \sqrt{k_i} * P_i^{1-\sigma}\ \forall i$. This in turn implies that $t_{*ij}^{1-\sigma} = \sqrt{k_i k_j} * t_{ij}^{1-\sigma}$.

After obtaining all the trade costs, step 2 suggests implementing a policy that will alter the trade costs. This is done by multiplying ${t_{ij}}^{1-\sigma}$ by a specific policy term a_{ij}. Then using (7) the MRs are recalculated using these new trade costs. Denote $\{P_i^{N1-\sigma}\}\ \forall i$ be the solutions to (7) and the new after policy MRs. Then (7) ⇒

$$(1d) \quad 1 = \frac{1}{\mathrm{P}_j^{N1-\sigma}}\left(\sum_i \frac{\theta_i a_{ij} {t_{ij}}^{1-\sigma}}{\mathrm{P}_i^{N1-\sigma}}\right) \quad \forall j$$

Now for the alternative internal trade costs this ⇒

$$(2d) \quad 1 = \frac{1}{\mathrm{P}_{*j}^{N1-\sigma}}\left(\sum_i \frac{\theta_i a_{ij} {t_{*ij}}^{1-\sigma}}{\mathrm{P}_{*i}^{N1-\sigma}}\right) = \frac{\sqrt{k_j}}{\mathrm{P}_{*j}^{N1-\sigma}}\left(\sum_i \frac{\theta_i a_{ij}\sqrt{k_i}\, t_{ij}^{1-\sigma}}{\mathrm{P}_{*i}^{N1-\sigma}}\right) \quad \forall j$$

Since (1d) = (2d) = 1 then $\mathrm{P}_{*j}^{N1-\sigma} = \sqrt{k_j} * \mathrm{P}_j^{N1-\sigma}\ \forall j$ is the one unique solution to (2d).

Now for the 3rd step, denote the counterfactual trade levels with an N superscript. Then for the 1st and 2nd set of internal trade costs this implies:

$$T_{ij}^N = \frac{Y_i Y_j a_{ij}}{Y_w}\left(\frac{t_{ij}}{\mathrm{P}_i^{N1-\sigma}\mathrm{P}_j^{N1-\sigma}}\right)^{1-\sigma} \quad \forall i,j \quad \sigma > 1 \qquad and$$

$$T_{*ij}^{N} = \frac{Y_i Y_j a_{ij}}{Y_w}\left(\frac{t_{*ij}}{\mathrm{P}_{*i}^{N1-\sigma}\mathrm{P}_{*j}^{N1-\sigma}}\right)^{1-\sigma} = \frac{Y_i Y_j a_{ij}\sqrt{k_i k_j}}{Y_w\sqrt{k_j}\sqrt{k_j}}\left(\frac{t_{ij}}{\mathrm{P}_{i}^{N1-\sigma}\mathrm{P}_{j}^{N1-\sigma}}\right)^{1-\sigma} \forall i,j \quad \sigma > 1$$

Then it is clearly seen that $T_{ij}^{N} = T_{*ij}^{N}$, and this completes the proof.

Appendix E: Data Description

Monthly data is gathered on countries based on data availability for the following periods in year.month

USA	1999.1- 2015.9	with Taylor Rule: 1999.1- 2015.9
China	1999.1 – 2013.11	with Taylor Rule: 1999.1- 2013.11
Malaysia	1999.1 – 2015.9	with Taylor Rule: 1999.1- 2015.7
Japan	1999.1 – 2015.9	with Taylor Rule: 1999.1- 2015.7
India	1999.1 – 2015.9	with Taylor Rule: 1999.1- 2015.6
Indonesia	2001.3 – 2015.9	with Taylor Rule: 2001.3- 2013.3
Philippines	1999.1 – 2013.4	with Taylor Rule: 1999.1- 2013.4
Thailand	1999.1 – 2015.9	with Taylor Rule: 2001.1- 2015.8
Korea	1999.1 – 2015.9	with Taylor Rule: 1999.1- 2015.5
Singapore	1999.8 – 2015.9	with Taylor Rule: 1999.8- 2015.8
Hong Kong	1999.6 – 2015.9	with Taylor Rule: 2000.1- 2015.8

Data on the 3 month interbank interest rates, exchange rates, forward rates, and NDF rates taken from Bloomberg.

Data on Industrial Production, Unemployment and inflation is taken from the IMF – International Financial Statistics.

Appendix F: The NDF Market

The non-deliverable forward (NDF) market is a market for forward currency contracts where physical currencies are not exchanged. In Asia these markets are located in Singapore and Hong Kong and 60 to 80 percent of activity is for speculative purposes. For a description see Misra and Behera (2006), Lipscomb (2002), and Shamah (2008). In our countries' sample China, India, Korea, and the Philippines had formed an NDF market since 1999. Indonesia joined the list in 2001. The last market that joined was Malaysia in 2005. Thailand does not have an official NDF market as it is discouraged by the Thai government; as stated in Misra and Behera (2006) there is an implied threat to participation of foreign banks that have branches in Thailand.

The market transaction is best illustrated by an example. Consider the NDF market for the Indian rupee. The transaction involves two counterparties. Both counterparties start the transaction by giving each other a fixed amount of rupees (on paper). The agreement is to return the rupees exchanged in dollars in the future period. One counterparty states an exchange rate that it would exchange the rupees for in the future period (this is the NDF exchange rate) while the other exchanges using the actual realized rate in the future period; no physical currency is exchanged and this is only on paper. Due to differences in the NDF and realized future exchange rate one counterparty will have more dollars than the other (on paper); the net difference is then settled in dollars and transferred to one of the counterparties.

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