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Price-level co-movements within currency unions : an alternative integration metric

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Price level co-movements within currency unions: an alternative integration metric

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Abstract

This paper analyzes currency union integration by testing whether price levels in member countries possess a common stochastic trend. The trace statistic test for cointegration proposed by Johansen (1995) demonstrates the presence of such a trend for most unions. A disaggregated analysis identifies a common stochastic trend for several though fewer than half of country pairs within a union, particularly compared to the set of country pairs not in unions. Some unions such as the Eurozone have small shares of cointegrated country pairs. Relative to countries outside currency unions, the share of cointegrated country pairs is large. Comparison to a control group (country pairs where one country belongs to a given union and the other country does not) indicates that the cointegration found within a currency union is a union-specific trait and not a feature of the individual countries

*gregorywhitten@ln.edu.hk, Assistant Professor, Lingnan University, Department of Economics. I am grateful to Steven Husted, David de Jong, and Zongxin Qian for valuable comments. Do not quote without permission within the union. These results provide an alternative metric to intra-union trade for gauging the extent of currency union integration.

1 Introduction

Intraunion trade flows have long been used to gauge the extent to which countries within a currency union are integrated (See Rose (2000) and Glick and Rose (2002), for example). However, recent work has called into question the reliability of this approach for characterizing currency unions. Glick and Rose (2015) revisit earlier work exploring the effect of a common currency on trade. Building on recent innovations to estimating bilateral trade flows with gravity equations, the authors conclude that "it is currently beyond our ability to estimate the effect of currency unions on aggregate trade with much confidence," (p. 19). Furthermore, Santos Silva and Tenreyro (2010) have suggested considering a wider range of criteria, beyond aggregate, intraunion trade, by which to characterize currency union formation and operation. One possible criterion, used in other studies of economic integration, is the co-movement of aggregate price levels in the union's member countries. Such co-movements would suggest the existence of a well-defined and unified market, a hallmark of an integrated economy. The goal of this paper is to investigate, for all currency unions, the extent to which prices are well-integrated; that is to say, does the price index of a currency union country co-move with the price indices of fellow currency union member countries in a manner consistent with the union's fixed exchange rate?[1]

Examining price co-movements as a measure of integration emerges easily from considering trade flows as a measure of integration. Previous work has shown that the

[1]See page 38 for a list of currency unions and their members.

extent of trade integration within a currency union varies across the set of unions; depends largely on the tariff structure operating within the currency union countries; and is greater for manufacturing goods than for agricultural goods (See Whitten (2013), Whitten (2014), and Glick and Rose (2015)). More opportunities for trade should permit more opportunities for low-cost producers in one currency union member country to sell into markets with relatively-higher cost producers within the currency union, leading to greater trade. Thus, any productivity gains in one country within a currency union that is well-integrated through trade should lead to slower growth in prices for that country and manifest itself throughout the entire currency union. Such active trading should lead the prices of goods to attain a common level and/or growth rate throughout the union. These effects on prices are not only a feature of currency unions but a necessary attribute for the long-run maintenance of the fixed exchange rate that defines the currency union.

To argue that price co-movements can serve as a reliable metric for the integration of currency unions requires demonstrating the following statements. First, price levels among currency union members move together. Second, price levels among countries outside currency unions do not move together or move together to a lesser extent than those within a currency union. Third, the co-movements identified among currency union countries are a consequence of the union itself and not of country-specific traits that could manifest themselves in relation to countries outside the currency union in question.

This paper accomplishes these tasks by testing price levels for a cointegrating vector using the Johansen (1995) approach. To accomplish the first statement, this paper tests for the presence of a cointegrating vector among the price levels of the currency union's member countries: "multilateral" cointegration. The results show that most, though not all, currency unions possess a cointegrating vector among their members. This finding definitely suggests a high level of economic convergence within the union, but does not demonstrate that this level of convergence is unique to currency unions or surpasses convergence found outside unions. Furthermore, characteristics of certain currency unions complicate testing for long-run behavior. Several currency unions (e.g., the CFA zones in Africa, the East Caribbean Currency Union) comprise developing economies for which the availability of data is limited. Additionally, entrances into and exits out of unions (e.g., countries adopting the US dollar on an *ad hoc* basis) can shorten the timespan over which the cointegration test can examine a union's entire membership. As a result, the multilateral approach may be insufficient to establish price co-movements as a reliable metric to characterize currency union integration.

To overcome these problems and to demonstrate the second and third statements, the paper replicates the finding of union-wide cointegration by testing for cointegation on a pairwise basis for all unique pairs of countries within a particular currency union: "bilateral cointegration." The results show that currency unions with a cointegrating vector at the multilateral level have a high share of country pairs that exhibit cointegration while currency unions without a cointegrating vector at the multilateral level have a low share of country pairs that exhibit cointegration. This replication allows for considering 2 control groups in order to distinguish currency unions from other groups of countries. The first control group consists of all country pairs where neither country belongs to a currency union. The second control group consists of all country pairs where exactly one country belongs to a particular currency union and the other country does not belong to that particular currency union: "partial" currency unions. The second control group is designed to test whether or not the finding of cointegration at the multilateral level is truly a consequence of the union itself or reflects country-specific features. As most currency unions consist of small, open economies, these countries (as well as other small, open economies) might exhibit cointegration in their price levels with the price levels of many other economies inside or outside the currency union. Finding large rates of cointegration among the partial unions would indicate the latter while a low rate of cointegration among the partial unions would indicate the former.

This paper also shows that even if price levels for some countries within a currency union lack cointegration, the growth in the price level of currency union country responds, in a Granger causal sense, to growth from the price level of another union member. However, Granger causality in price levels does not happen more frequently within a currency union than does it happen outside a currency union.

Consequently, several currency unions exhibit at least one feature of a single, well-integrated economy. As previous work has described, the extent of this integration differs tremendously across the set of unions. Therefore, the finding that some currency unions demonstrate little or no cointegration of overall price levels may be unsurprising. A more surprising result is that a common stochastic trend exists on a bilateral basis rarely for more than half of all country pairs. However surprising this result may be, it argues for a high level of integration, relative to countries outside currency unions, among currency union countries. This conclusion arises from the finding that country pairs not sharing a common currency possess a common stochastic trend even more rarely (approximately 7% of all pairs). That rate of cointegration is comparable to the rates for the "partial" unions consisting of country pairs where one country belongs to a particular currency union and the other pair does not. Hence, currency union pairs are cointegrated far more frequently than are non-currency union pairs by comparison. This finding is an attribute of the union itself and does not reflect idiosyncratic characteristics of the currency union members.

This paper also considers an alternative explanation to the cointegration findings, that they arise from the Penn or Balassa-Samuelson effect: the income and price levels of a country are positively correlated. Hence, co-movements in prices over time may be the consequence of income levels co-moving over time (See Lipsey et al. (1991)). Therefore, the cointegration findings in this paper for currency unions may not indicate greater integration but may be a consequence of income growth. To address this concern, the paper analyzes the averages over time of cross-sectional standard deviations of income. If the dynamic co-movement of prices reflects a consistent, dynamic growth of income, then income levels across a currency union at any moment in time should not be "too spread out." If this low variance persists over time, then the average of the standard deviations (to measure the range of income) should be low: a negative correlation between the extent of price co-movement over time (the rates of cointegration) and the average over time of cross-sectional standard deviations. The paper finds that though there is a negative correlation, its weak value makes the Balassa-Samuelson effect an unlikely, primary explanation for the cointegration findings.

The overall extent of integration suggested by the results in this paper concurs with the extent of integration found in previous work for some unions such as the UEMOA and ECCU (Whitten (2013) and Whitten (2014)). Other unions (CEMAC and dollarized countries) exhibit a common stochastic trend overall but are poorly-integrated through trade (Whitten (2013), Klein (2005), and Gulde and Tsangarides (2008)). Dollarized countries as well as the Eurozone have few instances of country pairs within the unions demonstrating cointegration. This result may be expected as Whitten (2013) indicates that these unions appear to be little integrated by trade. However, though Gulde and Tsangarides (2008) and Whitten (2013) also indicate that the CEMAC is little integrated by trade, this paper finds that over half of the country pairs within the CEMAC exhibit cointegration. The anchor-client relationship of India and Bhutan appears to be well-integrated by trade and demonstrates Granger causality but lacks cointegration.

Although this paper may be the first work to compare the behavior of price dynamics across the set of all currency unions, it is not the first to use price dynamics to study the extent of integration within a set of countries. The prospect of a single European market prompted research that investigates inflation patterns across areas using a similar currency, often using American price behavior at the city or state level to provide a benchmark against which to compare the emergence of an integrated market within the Eurozone. Certainly, the economic links among cities and states/provinces within a country likely differ from the links among countries. However, characterizing these links provides a reference point, presumably an upper bound, against which we can gauge currency union integration.[2] Cecchetti et al. (2002) conduct unit root tests on regional CPIs within the United States in order to envision "the likely nature of inflation convergence in the euro area," (p. 1081). The authors find that the half-life of a price shock within the United States is approximately nine years, a surprisingly large amount of time for an economy thought to be as well-integrated as the United States. Canova and Pappa (2007)

[2] I thank an anonymous referee for reminding me of this distinction.

look at the dynamics of price indices in response to fiscal shocks in American states and European countries in order to obtain a benchmark standard of what constitutes integration. Rogers (2007) examines the dispersion of individual goods' prices as well as of price indices. Comparing the dispersion of prices in European cities with the dispersion of prices in American cities, the paper concludes that the preparations for the euro reduced price dispersion, that dispersion has not decreased since 1998, and that price dispersion is still larger in the Eurozone than in the United States. Faber and Stokman (2009) find slightly greater integration than does Rogers (2007) for both tradable and non-tradable goods. Crucini et al. (2012) uses product level data to test for the Law of One Price within the United States.

The justification for using inflation patterns within the United States to forecast, in a very general sense, the nature of inflation convergence in the Eurozone, arises from the United States being "a mature common currency area of similar regional diversity, size, and industrial development," (Cecchetti et al. (2002), p. 1081). A similar examination using the other currency unions operating in the world also provides a useful comparison. Like the Eurozone countries, the member nations of other currency unions are sovereign states that retain a large degree of fiscal autonomy. Therefore, examining movements of price indices within a currency union and comparing those movements for all currency unions (Eurozone and others) provides an instructive lesson regarding price level convergence over an area using the same currency but consisting of multiple countries.

The European Monetary Union (EMU) has received arguably the largest amount of attention of any currency union on the subject of price convergence. Research in this area has often but not always used cointegration methods to study price dynamics.

Hagen and Fratianni (1990) and Kirchgössner and Wolters (1993) test for cointegration in order to verify whether or not members of the EMS (precursor to the EMU and Eurozone) could follow a largely German-inspired monetary policy. Kočenda (2001) finds the extent of cointegration in the 1990s between Germany and transitioning economies in the 1990s from the former Soviet Union was rather low. Brada and Kutan (2001) obtained similar results, though the authors found that new adherents to and propspective candidates for the EU had higher levels of economic convergence with Germany. Brada et al. (2005) consider not only Germany but France as well when examining the economic convergence (measured by cointegration) between core EU members and transitioning economies presenting themselves as EU candidates. Lopez and Papell (2012) develop a novel panel technique to study economic convergence among EU members at key dates before and after the introduction of the euro. The authors use their technique to reject, weakly and strongly, the presence of a unit root in inflation patterns among EU countries. The authors link the strength with which they reject the unit root to economic events. E.g., the authors reject strongly the unit root hypothesis between 2005 and 2007 when the authors conclude that EU economies have converged. However, the authors can reject the unit root hypothesis only weakly after 2008, attributing the shock of the financial crisis to their findings.

Surprisingly, it appears that few have undertaken the task of examining carefully the pattern of price movements among the countries constituting a single currency union other than the Eurozone. Crucini and Yilmazkuday (2014) use product-level price data to test for the Law of One Price and Purchasing Power Parity across a wide number of cities and countries. Although several of these cities are in countries that belong to a currency union (e.g., Dakar, Singapore, Lisbon), the paper does not examine currency unions in particular. Abdih and Tsangarides (2010) use cointegration and Granger causality tests, also used here, in order to examine the two *Communauté financière africaine* (CFA) zones (CEMAC and UEMOA), but only at a union-wide level rather than for individual countries. More recently, Couharde et al. (2013) examines currency misalignment within the CFA zones (the UEMOA and CEMAC) in terms of trade and GDP.

The organization of this paper is as follows. Section 2 describes the methodology and data used in this paper. Section 3 shows results when looking at the countries within a currency union, one union at a time. Section 4 presents a disaggregated analysis that looks at individual pairs of countries within a currency union as well as pairs where one country belongs to a given currency union and the other country does not.

2 Methodology & Data

This paper's contribution is an analysis of currency unions and their integration by examining inflation patterns among a given union's member countries. Well-integrated economic regions (such as the members of a currency union) should exhibit a common inflation pattern over time, a pattern that is robust to unexpected and transient disturbances. This economic concept of integration for a currency union of n countries translates into a statistical test for a set of n coefficients, $(\beta_0, \beta_1, \ldots, \beta_n)$ such that, on average:

$$\beta_0 + \beta_1 p_1 + \ldots + \beta_n p_n = 0 \tag{1}$$

where p_i denotes the log of the price level. Equation 1 states that the vector of coefficients ensures that, on average, the linear combination of coefficients and price levels will be stationary. To test for this vector, this paper uses the approach in Johansen (1995) applied to the log of the Consumer Price Indices (CPIs). The CPIs approximate the price level of the countries inside and outside currency unions. The Johansen (1995) approach assumes a Gaussian distribution and uses Maximum Likelihood Estimation in order to identify parameters from the following estimating equation:

$$\begin{bmatrix} \Delta p_{1t} \\ \vdots \\ \Delta p_{nt} \end{bmatrix} = \pi_0 + \alpha\beta' \begin{bmatrix} p_{1t-1} \\ \vdots \\ p_{nt-1} \end{bmatrix} + \sum_{i=2}^{l} \pi_i \begin{bmatrix} \Delta p_{1t-i} \\ \vdots \\ \Delta p_{nt-i} \end{bmatrix} + \epsilon_t \tag{2}$$

where l is the lag-length of the system, $\alpha\beta'$ is an $n \times n$ matrix consisting of 2 $n \times r$ matrices (where r represents the number of cointegrating vectors) and the remaining π_i are $n \times n$ matrices. The Johansen procedure normalizes one coefficient in the cointegrating vector to 1 and may impose other coefficients to be 0. β_1 will denote in this paper the coefficient normalized to 1.

The choice of the lag length plays a key role in testing for cointegration (see Reimers (1992) and Boswijk and Franses (1992)). This paper chooses the lag length in a manner similar to that followed by Rapach and Wohar (2002) and Baharumshah et al. (2010). First, the `varsoc` command in Stata estimates VARs on the data for lag lengths varying from 1 to 5. 5 is the maximum number used by Rapach and Wohar (2002) whose data, like the data in this paper, are measured at quarterly frequencies. Next, given the results, the lag length for the Johansen procedure is the length that minimizes the Schwarz's Bayesian Information Criterion (SBIC) for the above-mentioned VARs. The Stata manual cites Lütkepohl (2005) in stating that "the SBIC or the HQIC provides consistent estimates of the true lag order," while "minimizing the [Akaike Information Criterion (AIC)] ... will overestimate the true lag order with positive probability, even with an infinite sample size."[3] Consequently, SBIC appears to be preferable to AIC. Given the lag length implied by the SBIC, the `vecrank` command in Stata estimates equation 2 for r cointegrating vectors where r is also dictated by the results from the `vecrank` test.

Given the cointegration estimates, what inferences are possible regarding the extent (if any) of integration within a currency union? Suppose that a currency union has 2 countries (as is the case for Singapore-Brunei and India-Bhutan). If such a union were perfectly integrated then the trend of the price level in one country would just offset the trend in the price level of the other country. I.e., the cointegrating vector for this union would be $(1, -1)$. Note that this is the same result one would find if absolute Purchasing Power Parity (PPP) held for a fixed exchange rate equal to 1 between the two countries.

Suppose, more realistically, that a currency union had more than 2 countries. It is not immediately obvious which values of the coefficients would indicate a large level of integration. Certainly, as price levels tend to rise over time, any positive coefficient for one country's price level should be offset by a negative coefficient for another country's price level. Beyond these expectations on the signs of the coefficients, it is not obvious which values the coefficients should take. Given that β_1 is normalized to 1, the results will test each coefficient of the cointegrating vector against a null hypothesis of $\beta = -1$

[3]Accessed online at `http://www.stata.com/manuals13/tsvarsoc.pdf`, p. 3

as well as $\beta = 1$, those values being chosen as reasonable benchmarks for measuring the extent to which the price levels of countries respond to movements in the price levels of other countries. If a coefficient were significantly different from 0 but insignificantly different from -1 it would counteract with equal weight the (presumably upward) long-run trend of p_1 (as β_1 is normalized to 1). If a coefficient were significantly different from 0 but insignificantly different from 1, it would reinforce the (presumably upward) long-run trend of p_1. It is important to consider differing significantly from 0 because relying merely on a failure to reject a null of $\beta = 1$ or $\beta = -1$ would not rule out cases where a large standard error would admit 0 as a possible value for the coefficient.

Analyzing the long-run behavior of price levels for a group of countries requires as long of a span of data for the countries in question as is possible. If data for one or more countries are unavailable for certain length of time (a frequent phenomenon for developing economies who are the majority of countries in currency unions), then testing for cointegration over the full membership of the currency union becomes less reliable. Changes in the currency union's membership over time because of countries joining or leaving further complicates the problem. This paper proposes 2 remedies for this problem. First, note that the bilateral analysis where a currency union is seen as a set of country pairs ensures that the full timespan of data is used to study price level dynamics. For example, if a union consisted of 3 countries for 40 years and recorded data existed for 2 of the 3 countries for the 40 years but the 3rd country possessed data only for 20 years, the cointegration test for the full currency union (multilateral analysis) could take place only over 20 years of data. With the bilateral analysis, the full 40 years of data could be used to study the pairwise movements in price levels for the first 2 countries. More information should provide a more reliable characterization of the currency union. A second remedy is to test a currency union for cointegration multiple times but changing the exact composition of the countries each time. The first test will be on the entire currency union membership. Each subsequent test drops one country at a time, the country with the smallest number of observations. The process verifies the sensitivity of the results and permits obtaining a longer sample period of data. The longer sample period should improve the power of the test, facilitating a rejection of the null hypothesis of no cointegration. The cost of this procedure is that removing a country may remove a price level that plays a key role in identifying a common stochastic trend throughout the currency union.

Another remedy for the small T problem is to increase artificially the number of observations by increasing the frequency of the observations (quarterly versus yearly or monthly versus quarterly). Brada et al. (2005) and Lopez and Papell (2012) use monthly data for their rolling procedures. However, the higher the frequency of the data, the more likely that high-frequency noise might infect the data and obscure the existence of a cointegrating vector. Given these trade-offs, this paper uses the CPI measured at quarterly frequencies and published in the IMF's International Financial Statistics database, 1948-2014. Identification of currency union membership comes from Glick and Rose (2002) with updates from IMF Staff Reports.

3 Currency union-wide investigation

This section reports results from cointegration tests for the log of the CPI for member countries within a currency union. The results are reported in tables 1 through 11. The tables list the estimated coefficients for the cointegrating vector, the standard errors, and 3 Z-scores for different null hypotheses: $\beta = 0$, $\beta = 1$, and $\beta = -1$. Recall that the Johansen approach normalizes the coefficient for one country to 1. Consequently, there is no standard error for this coefficient. A 0 with no standard error implies that the Johansen procedure normalized that coefficient to 0. A blank entry in the column for $\hat{\beta}$ means that the country is not included in the test over the time-period specified by the column.

Table 1: Currency unions with no cointegrating vectors

Time-period	1976Q3 - 1990Q4	2003Q4 - 2014Q1	2000Q2 - 2013Q4
Countries	Australia	Bhutan	Brunei Darussalam
	Tonga	India	Singapore

Most currency unions possess a cointegrating vector, though the results are sensitive to the composition of countries and time frame examined. Among the smaller unions described in table 1, none exhibit cointegrating relationships. The time span for which data are available may be small, particularly for India-Bhutan and Brunei-Singapore. Given that cointegration is a long-run property, the absence of cointegration for the India-Bhutan and for Singapore-Brunei may be a consequence of the short length of time over which data are available. However, India-Bhutan and Brunei-Singapore have operated for several decades, during which price levels should have adjusted and converged to overcome any long-run disturbances. Furthermore, Whitten (2013) shows that India and Bhutan were well integrated by trade, even conditioning on tariffs. Therefore, it is surprising that the price disturbances in each union are sufficient to prevent the rejection of the null of no cointegration even when examined with a short span of recent data.

Table 2: Time periods examined for EMU cointegration

2008q2 - 2013q4
2007q2 - 2013q4
2005q3 - 2013q4
2004q3 - 2013q4
2002q3 - 2013q4
2000q3 - 2014q2

More surprisingly may be the absence of cointegration from the European union, particularly when compared with the results of Brada et al. (2005) and Lopez and Papell (2012), even after examining six different periods of time (see table 2). On one hand, the relatively short existence of the euro may explain the absence of cointegration as the result of a small sample of time. On the other hand, EMU member countries have a long history of aligning their exchange rates. Unexpectedly, this history seems to have had no effect on inducing a common pattern of inflation across EMU member countries.

Table 3: Cointegrating vectors for the Rand zone

	1973q2 - 1997q1				
	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$
Lesotho	1.0				
Swaziland	-2.054	0.362	-5.68	-8.44	-2.913
South Africa	1.057	0.364	2.9	0.156	5.65

The Rand zone, described in table 3, exhibits cointegration. The coefficient for South Africa's price level is significantly different from 0 and insignificantly different from 1. The coefficient for Swaziland is -2.054, implying that Swaziland's price level counteracts the approximately-equally weighted movements in the price levels for South Africa and Lesotho.

The CEMAC, results for which are in tables 4-6, show that cointegration exists over multiple spans of time and for multiple subsets of the union. From the early-to-mid 1980s to the first quarter of 2014, the results indicate that the price levels of CEMAC member countries move together. However, the movements of individual countries are generally not of equal magnitude, as demonstrated by the coefficients of the cointegrating vector that are largely different from 1 or -1. The exceptions to this pattern occur during the time period of 1984q3 to 2014q1. The coefficient for Cameroon, 0.682, is significantly different from 0 while the Z-score against a null-hypothesized value of 1 is rather small in absolute value, suggesting borderline insignificance. A similar result applies for the coefficient on Chad, -1.323, when compared with a hypothesized value of -1. The coefficient on Gabon is insignificant. Hence, movements in Chad's price level tend to counteract the combination of price movements from Cameroon and the Central African Republic.

The CFA Franc was devalued against the French franc in 1995 (see Masson and Pattillo (2005)). Hence, consider the time-series of data in 2 parts (pre- and post-devaluation) for the CEMAC as well as for the UEMOA. Generally speaking, cointegration occurs both before and after the devaluation, though the pattern of the coefficients on the cointegrating vector changes noticeably before and after the devaluation. The cointegrating vector for 1985q2 - 1994q4 (see table 5) imposes a 0 coefficient on Cameroon. The coefficient on Chad, -1.073, is significantly different from 0 but insignificantly different from -1 while the other coefficients are largely insignificant. This result is comparable to the time period of 1984q3 to 2014q1 discussed earlier.

Table 4: Cointegrating vectors for the CEMAC

	1981q3 - 2014q1					1984q3 - 2014q1					1985q2 - 2014q1				
	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$
Central African Republic	1.0					1.0					1.0				
Cameroon	0.524	0.174	3.01	-2.737	8.752	0.682	0.21	3.25	-1.514	8.015	0.0				
Republic of the Congo															
Gabon	-2.041	0.281	-7.27	-10.835	-3.708	-0.306	0.312	-0.98	-4.186	2.225	0.0				
Equatorial Guinea											0.454	0.204	2.22	-2.671	7.116
Chad						-1.323	0.2	-6.63	-11.64	-1.619	-1.615	0.293	-5.51	-8.921	-2.099

Table 5: Cointegrating vectors for the CEMAC (continued)

	1981q3 - 1994q4	1984q3 - 1994q4					1985q2 - 1994q4				
		$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$
Central African Republic		1.0					1.0				
Cameroon		0.142	0.139	1.02	-6.17	8.208	0.0				
Republic of the Congo											
Gabon		-0.358	0.202	-1.77	-6.708	3.175	-0.334	0.185	-1.81	-7.223	3.604
Equatorial Guinea							-0.094	0.159	-0.59	-6.888	5.706
Chad		-1.337	0.176	-7.61	-13.295	-1.92	-1.073	0.194	-5.53	-10.676	-0.375

Table 6: Cointegrating vectors for the CEMAC (continued)

	1996q2 - 2014q1	1998q2 - 2014q1				
		$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$
Central African Republic		1.0				
Cameroon		-2.16	0.366	-5.9	-8.627	-3.167
Republic of the Congo		0.767	0.14	5.48	-1.67	12.64
Gabon		-1.021	0.226	-4.51	-8.937	-0.091
Equatorial Guinea		0.281	0.105	2.67	-6.833	12.171
Chad		-0.067	0.09	-0.75	-11.915	10.418

Table 7: Cointegrating vectors for the Dollarized zone

	1973q2 - 1987q4					1973q3 - 2014q2					1957q3 - 2014q2				
	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$
Bahamas	1.0					1.0									
Dominican Republic	0.0					-0.198	0.048	-4.09	-24.714	16.539	1.0				
Guatemala	-0.127	0.033	-3.89	-34.595	26.811										
Panama	0.014	0.172	0.08	-5.735	5.899	-0.391	0.293	-1.33	-4.74	2.076	2.048	1.313	1.56	0.798	2.321
USA	-0.711	0.156	-4.56	-10.984	1.855	-0.295	0.308	-0.96	-4.207	2.289	-3.736	0.869	-4.3	-5.447	-3.147

Examining a time period following devaluation, 1998q2 - 2014q1 (see table 6), the coefficient on Cameroon is -2.16 and significantly different from 0. The coefficient on Chad, in contrast, is insignificantly different from 0. The coefficient for the Republic of Congo, 0.767, is significantly different from 0 and borderline insignificantly different from 1. The coefficient for Gabon, -1.021, is also significantly different from 0 and insignificantly different from -1. The coefficient for Equatorial Guinea is also significantly different from 0 but also significantly different from 1 or -1. Although the devaluation did not prevent the price levels of CEMAC countries from regaining a stable, long-run relationship, the results indicate that the role and importance of individual countries has changed following the devaluation. Transitioning from one type of long-run relationship among price levels to another long-run relationship among price levels may explain the absence of a cointegrating vector immediately following the devaluation (1996q2-2014q1) even though it has merely 8 more quarters than does the time period of 1998q2 - 2014q1 when cointegration is present.

The results for dollarized countries (table 7) show cointegration over several, long durations. In most cases, the coefficients indicate that the price levels of countries sharing the US dollar do not move in equal measure. Most coefficients that are significantly different from 0 are also significantly different from 1 and from -1.

The ECCU exhibits cointegration over multiple time periods of varying lengths (see tables 8 - 9). In the shortest and most recent time period, 1998q2 - 2013q4, all coefficients are significantly different from 0, except the coefficient for St. Lucia. 3 countries (Antigua & Barbuda, Grenada, and St. Vincent & the Grenadines) have coefficients that are significantly different from 0 but insignificantly different from -1. The coefficient on

Table 8: Cointegrating vectors for the ECCU

	1998q2 - 2013q4					1980q2 - 2013q4				
	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$
Anguilla	1.0									
Antigua & Barbuda	-0.966	0.266	-3.63	-7.388	0.129					
Dominica	3.077	0.452	6.8	4.593	9.016	1.0				
Grenada	-1.299	0.387	-3.36	-5.946	-0.774	-3.33	0.411	-8.1	-10.527	-5.665
St. Kitts & Nevis	-0.625	0.18	-3.47	-9.016	2.079	1.49	0.211	7.07	2.327	11.817
St. Lucia	-0.13	0.191	-0.68	-5.93	4.562	-0.276	0.297	-0.93	-4.298	2.438
St. Vincent & the Grenadines	-0.719	0.241	-2.98	-7.134	1.168	0.743	0.447	1.66	-0.574	3.9

Table 9: Cointegrating vectors for the ECCU (continued)

	1979q2 - 2013q4					1976q3 - 2013q4				
	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$
Anguilla										
Antigua & Barbuda										
Dominica										
Grenada	1.0									
St. Kitts & Nevis	-0.347	0.077	-4.5	-17.457	8.457	1.0				
St. Lucia	-0.175	0.112	-1.56	-10.471	7.345	-0.322	0.366	-0.88	-3.61	1.85
St. Vincent & the Grenadines	-0.316	0.108	-2.92	-12.149	6.313	-0.513	0.381	-1.35	-3.967	1.277

Dominica, 3.077, is significantly different from 0 as well as from 1. Hence, three countries each of whose coefficients is approximately -1 as well as one more country (St. Kitts & Nevis: -0.625) counteract the influence of one country (Dominica) with a coefficient approximately equal to 3 plus the influence of a country with a coefficient normalized to 1 (Anguilla).

The UEMOA, as is the case with its fellow CFA member the CEMAC, (see tables 10 - 11) displays cointegration over nearly all time periods examined. As is the case with the CEMAC, these results suggest a change after 1994 in how movements in the price levels of different countries in the UEMOA respond in order to maintain a stable price level. The third panel of table 10 and the first panel of table 11 indicate that both before and after the devaluation of the CFA franc, price levels in the member countries move together. Considering the latter case, 2 countries (Côte d'Ivoire and Mali) have coefficients that are significantly different from 0 but insignificantly different from -1. Senegal's coefficient is 1.528, significantly different from 0 (as well as from 1). Hence, the sum of price level movements in Burkina Faso and Senegal counteract the sum of price level movements from Côte d'Ivoire and Mali while Niger has a small and insignificant effect on the cointegrating vector.

The second panel of table 11 examines a set of countries nearly identical to those in the first panel of the same table.[4] Burkina Faso maintains a normalized coefficient of 1. However, the coefficient for Côte d'Ivoire is now positive, smaller in magnitude, and borderline significant. Niger and Senegal now each have significant and negative coefficients. Hence, the sum of price level movements in Burkina Faso and Côte d'Ivoire

[4]The coefficient for Benin is normalized to 0, rendering the situation comparable to that for 1988q1 to 2014q2 where Benin is excluded.

Table 10: Cointegrating vectors for the UEMOA

	1968q2 - 1994q4	1970q2 - 1994q4					1968q3 - 2014q2				
		$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$
Benin											
Burkina Faso		1.0					1.0				
Cote d'Ivoire		0.774	0.429	1.8	-0.525	4.133	-0.511	0.065	-7.86	-23.243	7.527
Guinea-Bissau											
Mali											
Niger		1.608	0.369	4.36	1.651	7.076	-0.231	0.056	-4.13	-22.035	13.778
Senegal		1.228	0.397	3.1	0.575	5.617	-0.072	0.084	-0.87	-12.835	11.1
Togo		-4.737	0.73	-6.49	-7.859	-5.119					

Table 11: Cointegrating vectors for the UEMOA (continued)

	1988q1 - 2014q2					1996q2 - 2014q2					1997q2 - 2014q2				
	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$	$\hat{\beta}$	Standard Error	Z-score for $H_0 : \beta = 0$	Z-score for $H_0 : \beta = 1$	Z-score for $H_0 : \beta = -1$
Benin						0.0					0.0				
Burkina Faso	1.0					1.0					1.0				
Cote d'Ivoire	-0.924	0.14	-6.59	-13.727	0.544	0.209	0.131	1.6	-6.054	9.245	0.014	0.117	0.12	-8.464	8.702
Guinea-Bissau											0.597	0.092	6.5	-4.388	17.394
Mali	-1.207	0.204	-5.93	-10.834	-1.018	0.139	0.185	0.75	-4.642	6.143	-0.173	0.166	-1.04	-7.072	4.99
Niger	-0.091	0.154	-0.59	-7.073	5.89	-0.624	0.218	-2.87	-7.465	1.728	-0.89	0.199	-4.48	-9.517	0.552
Senegal	1.528	0.255	5.99	2.071	9.914	-1.058	0.217	-4.88	-9.493	-0.267	-0.889	0.188	-4.72	-10.037	0.589
Togo															

counteract the sum of price level movements from Niger and Senegal while Mali has a small and insignificant effect on the cointegrating vector. As was the case in the CEMAC, devaluation appears to be associated with a rearranging of which countries counteract which other countries to maintain stable inflation patterns within the currency union.

The results in this section indicate that within a given currency union, countries attain stable inflation dynamics when some countries have positive coefficients (by normalization or otherwise) that accentuate growth in the price level while the negative coefficients on the price levels of other countries counteract that effect. Hence, it seems that countries sharing a common currency have price levels that move together. However, there are limitations to this conclusion. First, there are several cases where countries must be dropped in order to compute a cointegrating vector in a given time period. Therefore, the results may not be generalizable to the entire union. Second, the union-wide cointegration analysis finds no cointegrating vector for the EMU despite a long history of economic interaction among EMU member countries. Third, although these results demonstrate that the price levels of countries within a currency union move together, the results do not say that this comovement is unique to currency union countries or occurs more frequently among countries in a currency union than among countries not in a currency union.

To address some of these limitations, the next section will examine cointegration on a bilateral basis. Instead of looking at a currency union directly as a single entity, the bilateral analysis permits examining the union as a set of country pairs. As the bilateral analysis requires the availability of data for just 2 countries instead of more than 2 countries (the requirement for the multilateral analysis), it permits analyzing the price levels over longer periods of time. The examination takes place for pairs of countries that share a common currency as well as for pairs of countries using different currencies. For country pairs where each country uses a distinct currency, the test for cointegration is among price levels and the exchange rates. The theory of PPP dictates that if a common stochastic trend governs the price levels in a pair of countries, it should also govern a trend for the exchange rate. Ignoring the exchange rate component would lead to biased estimates. The next section follows a methodology similar to the methodology used by Berkowitz et al. (1998) of conducting cointegration tests on country pairs followed by Granger causality tests on those pairs. To understand if a given country has a particular influence on the price movements of another country within the union, the next section will report results from Granger causality tests on the price levels in country pairs.[5] This provides an extra dimension for understanding price dynamics across countries.

4 Bilateral Investigation

This section reports results from pairwise tests of cointegration and Granger causality for the log of the CPI. Table 12 shows the share of country pairs within each currency union that exhibit cointegration in the log of the CPI as well as the shares of Granger causality from the price level in one country to the price level in another.

Most currency unions consist of pairs of countries between which cointegration exists. Unions with zero or low rates of cointegration (the Australia zone, India-Bhutan, Singapore-Brunei, and the Eurozone) are unions lacking a multilateral cointegrating vector. Hence, the bilateral analysis generally confirms that found in the multilateral analy-

[5]For country pairs not in currency unions, I test only the null hypothesis that the lags of p_1 do not Granger cause the current value of p_2. I do not consider an exchange rate Granger causing price levels.

Table 12: Frequencies (%) of cointegration and Granger Causality within currency unions

Currency Union	Cointegration	Granger Causality
Australia zone	0.00	0.00
CEMAC	64.71	58.82
Dollarized zone	40.00	38.00
ECCU	36.67	35.00
Eurozone	19.66	32.91
India-Bhutan	0.00	100.00
Rand zone	33.33	33.33
Singapore-Brunei	0.00	0.00
UEMOA	50.00	62.50
A country pair not in a currency union	7.00	42.80

sis. The unions have rates of cointegration noticeably higher than the rate found among pairs of countries where neither country belongs to a currency union (7%). Interestingly, the currency union with the largest frequency of cointegration is the CEMAC (%64.17). Previous work has suggested that the CEMAC is the less integrated of the 2 CFA zones when integration is measured by trade. (See Gulde and Tsangarides, 2008 and Whitten (2013)). Half of the country pairs in the other CFA zone, the UEMOA, display cointegration, indicating that it remains as one of the more-integrated currency unions.

The union with the next largest frequency of cointegration (%40) is the group of countries sharing the U.S. Dollar. Surprisingly, this frequency of cointegration surpasses the frequency of cointegration in the ECCU, the Eurozone, and the Rand zone. The Eurozone has the lowest frequency of cointegration among any of the currency unions with non-zero instances of cointegration. This result may not be surprising in light of the lack of a union-wide cointegrating vector from the previous section.

The cointegration results not only describe the nature of price movements within a currency union. They also inform how Granger causality tests should be conducted. If the price levels are cointegrated for a given country pair, then the Granger causality test for the price levels of that country pair should be conducted on the levels themselves. Lacking cointegration, the Causality test is performed on first differences of the price levels, as price level data that are not cointegrated are generally thought to be non-stationary in levels but stationary in first differences. See Berkowitz et al. (1998) for more detail.

Rates of Granger Causality within currency unions are generally comparable to rates of cointegration. A key difference is the frequency of Granger Causality between non-currency union countries is much higher (42.8%) than is the frequency of cointegration between non-currency union countries (7%). The interpretation of this result is that price levels and exchange rates rarely follow a common stochastic trend. However, the change in the price level for one country often influences the change in the price level for another country. In fact, the influence of the price level in one country is more likely to affect the price level in another country when both countries are outside a currency union than if the pair of countries belongs to the Dollarized zone, ECCU, Eurozone, or Rand zone.

Although the results in table 12 generally confirm the results found in tables 1 through 11, there are some discrepancies. The cointegrating vectors found in the previous section suggest that prices move together over time for most currency unions. Taken literally, the numerous country pairs lacking cointegration, as demonstrated in table 12, suggest that the currency union cannot continue operating in its current form in the future, but is likely to fracture or dissolve. Possible explanations to reconcile the multilateral and bilateral results include the following. First, the data-generating process for price-level stability within the currency union may truly be multivariate instead of bivariate.

While the bivariate analysis of currency union pairs does provide a convenient control group against which to study the price dynamics of countries outside currency unions, the bivariate analysis alone may not describe fully the evolution of price dynamics inside a currency union. Hence, assembling an accurate depiction of price behavior throughout the currency union from a set of country pairs within the currency union may not be entirely feasible. Second, the cointegrating vectors found in the previous section over long time horizons often are calculated after dropping one or more countries from the analysis. Cointegrating vectors obtained for an entire set of currency union members often were obtained over relatively short horizons. Although cointegration is a long-run phenomenon, its presence over a short span of time does not rule out the possibility that for the entire set of countries in the currency union, the time period in question happens to be one of abnormally uniform growth in prices for all countries. For longer periods of time, a common stochastic trend may prevail truly only for a subset of countries.

To understand the results in table 12 more clearly, table 15 presents country pairs where there exists *any* price co-movement or causality. A separate appendix presents country pairs lacking any link between price levels through cointegration of Granger Causality. The column entitled "Coefficient for country 2" gives the cointegrating vector's coefficient for country 2 when the coefficient for country 1 is normalized to 1. The column $H_0 : \beta_2 = 0$ reports the Z-statistic from a test of the coefficient against the null hypothesis that $\beta_2 = 0$. Similarly, the column $H_0 : \beta_2 = -1$ reports the Z-statistic from a test of the coefficient against the null hypothesis that $\beta_2 = -1$. As nearly all of the $\hat{\beta}_2$ are negative, the results dispense with tests against a null hypothesis of $\beta_2 = 1$. A $\longleftarrow$ indicates that the price level in the second country indicated in the pair Granger causes the price level in the first country indicated in the pair. A $\longrightarrow$ indicates that the price level in the first country indicated in the pair Granger causes price level in the second country indicated in the pair. A $\longleftrightarrow$ indicates causality in both directions. Recall from page 12 that perfect integration in a bilateral context implies a cointegrating vector of $(1, -1)$.

In the CEMAC, nearly all country pairs that demonstrate Granger Causality also demonstrate cointegration. This result is largely consistent with the persistent finding of cointegration at the union-wide level, shown in tables 4 through 6. However, only 2 country pairs demonstrate perfect comovement of price levels: Chad - Cameroon and Republic of Congo - Central African Republic. Madagascar is never cointegrated with any other country or exhibits Granger Causality. Madagascar's departure from the CEMAC following treaty changes implemented by France in the 1970s may reveal a level of unsuitability between Madagascar and the currency union (Masson and Pattillo (2005)). Consequently, the lack of feedback between the price levels of other CEMAC countries and Madagascar should not be too surprising.

In the ECCU, no country pair satisfies the conditions for perfect price comovement, though there is a high frequency of cointegration. Some countries, notably St. Vincent & the Grenadines, are frequently cointegrated with other ECCU members. The only country with which St. Vincent & the Grenadines displays neither cointegration nor Granger Causality is Montserrat. This result likely is more informative about Montserrat than about St. Vincent & the Grenadines as Montserrat lacks cointegration and Granger Causality with all countries except for Antigua & Barbuda where it displays both.

To put the bilateral results for the ECCU in correspondence with the multilateral results in tables 8 and 9, consider the time period from 1998q2 to 2013q4. When the coefficient on Anguilla is normalized to 1, 3 countries (Antigua & Barbuda, Grenada, and St. Vincent & the Grenadines) have coefficients that are significantly different from 0 and insignificantly different from -1. On a bilateral basis, no country pair with Anguilla and any of the 3 other countries listed demonstrates cointegration. The Antigua & Barbuda - Grenada and Antigua & Barbuda - St. Vincent & the Grenadines pairs lacks cointegration but demonstrates Granger Causality. Only the Grenada - St. Vincent & the Grenadines pair demonstrates cointegration.

In the EMU, there are 3-5 country pairs that satisfy the criteria for exhibiting perfect price comovement. These pairs frequently involve newer or periphery countries within the EMU (notably Cyprus and Slovenia). Hence, these results may be anomalous rather than indicative of true economic integration. Unsurprisingly, Montenegro, which adopted the euro *ad hoc*, displays no co-movement in prices with the official members of the EMU except for Cyprus. In contrast, larger economies where one might expect a close relationship (such as Spain and Portugal or France and Germany) lack cointegration. On one hand, the absence of cointegration even on a pairwise basis may be a consequence of the euro's relatively short existence (approximately 15 years) when compared to the other monetary union currencies. However, other currency unions demonstrate cointegration in price levels over time periods of similar length (the ECCU, the CEMAC, and the UEMOA), undermining the short timespan as an explanation for the Eurozone's results. Also, given the long history of economic cooperation following World War II as well as attempts to link the exchange rates among future Eurozone members prior to 1999, the existence of cointegration for less than 20% of all country pairs is puzzling.

The Dollarized country pairs that demonstrate Granger Causality, like those in the

CEMAC, also demonstrate cointegration. Some countries, such as El Salvador, are frequently cointegrated with other countries. Other countries, such as the Dominican Republic, generally lack price co-movements with other countries. Although table 7 shows a cointegrating vector from 1957q3 to 2014q2 for the Dominican Republic, Panama, and the US, no 2 countries possess a cointegrating vector on a pairwise basis.

Although the UEMOA does not have the largest frequency of cointegration (50%, behind the CEMAC with 65%) only one country pair (Burkina Faso and Niger) lacks any pattern of price co-movement (either cointegration or Granger Causality). This relatively large frequency of integration through price dynamics is consistent with the high extent of trade integration for the UEMOA found in Whitten (2013). Country pairs containing Côte d'Ivoire, a large economy within the UEMOA, rarely exhibit cointegration but always exhibit Granger Causality.

Interestingly, the 3 countries (Burkina Faso, Niger, and Senegal) that regularly demonstrate comparable price comovements in tables 10 and 11 have very different behavior on a pairwise basis. Each of these 3 countries lacks cointegration on a bilateral basis with any of the other countries, though Granger causality exists for the pairs that include Senegal. Granger Causality exists in both directions for Senegal and Niger while Senegal Granger causes the price level in Burkina Faso. Given that the influence of Burkina Faso's price level movement changes direction over time with respect to the movements of Niger and Senegal after devaluation (see table 11), it may not be surprising that a pairwise examination with all available data yields no cointegration between Burkina Faso and either Niger or Senegal. More puzzling is the lack of cointegration between Niger and Senegal over the length of the sample, as the multilateral results indicate that the price levels in these countries move together both before and after the devaluation.

Clearly, more currency union pairs demonstrate price level comovements than do other pairs where neither country belongs to a currency union. One interpretation of this result is that the countries within a currency union genuinely represent a single, well-unified market. Another interpretation, however, is that the individual countries comprising the currency unions happen to possess individual characteristics that predispose their price levels to adjust more easily than other countries.

To examine which interpretation is more likely, consider the rates of cointegration in "partial currency unions" consisting of country pairs where exactly one country belongs to a particular currency union and exactly one country does not belong to that particular union. If individual countries possess characteristics that pre-dispose their price levels to adjust more easily than do the price levels of other counties, then the rates of cointegration should be comparable between the actual currency unions and the "partial" unions. In some cases, a particular country pair may belong to 2 "partial" currency unions. For example, the pair consisting of France and Liberia will belong to the "partial" EMU as well as the "partial" Dollarized zone. For the anchor-client unions (Australia zone, Dollarized Zone, India-Bhutan, Rand zone, and Singapore-Brunei), I exclude pairs that contain the anchor and any country outside the union. As an example, Tonga is the only country in the Australia zone other than Australia for which data exist. Consequently, table 13 indicates that there exists no cointegration between Australia and Tonga while 6% of country pairs consisting of Tonga and any country *other* than Australia demonstrate cointegration.

Cointegration in the "partial" unions is a rare phenomenon when compared with the

Table 13: “Partial” currency unions: 1 country in the named union, one country outside the named union

Currency Union	Cointegration	Granger Causality
Australia zone	6.0	33.10
CEMAC	7.0	41.08
Dollarized zone	8.0	45.90
ECCU	6.0	39.18
Eurozone	3.0	30.99
India-Bhutan	4.0	24.68
Rand zone	7.0	37.60
Singapore-Brunei	0.0	19.88
UEMOA	9.0	47.11

actual unions. The highest rate of cointegration for a partial union is with the members of the UEMOA where 9% of pairs consisting of one UEMOA member and one non-UEMOA country display cointegration. This frequency of cointegration resembles the rate of cointegration among country pairs outside currency unions (7%). Hence, by this metric, currency unions appear to be unified and well-formed. Price levels of a country pair within the same currency union adjust together more readily than do the price levels of 2 countries not in a currency union.

The Granger Causality results for the “partial” unions, however, do not distinguish currency union countries from non-currency union countries to the same extent that cointegration does. For some unions, the frequency of Granger Causality in the “partial” union is smaller than is the frequency in the actual union (such as the CEMAC and the UEMOA). However, the frequency of Granger Causality in some “partial” unions (such as the Dollarized zone, the ECCU, the Rand zone, and the Eurozone) exceeds or rivals the frequency of Causality in the corresponding actual union.

Overall, the price levels in currency union countries evolve in a manner consistent to the responses found in countries outside currency union countries. Unlike countries outside currency unions, however, the price levels of countries within a currency union move together at rates higher than those found outside currency unions. The fixed exchange rates of currency union members are more (though not perfectly) aligned with the price levels of the union's member countries than are the floating exchange rates aligned with the price levels of countries not sharing a common currency.

Could the results in the table be a consequence of the Balassa-Samuelson effect?[6] Recall that this effect refers to the fact that there exists a positive correlation between the price level of a country and its income level. If the incomes of a group of countries grow together over time, their price levels will move together over time, too. Therefore, the high rates of cointegration for countries in currency unions and the low rates of cointegration for countries not in currency unions (the "none" group and the partial unions) may be a consequence of the extent to which income levels vary within the groups in question. To consider the possibility that the common trend in price level is a consequence of price levels moving in tandem with income over time, table 14 presents the average, over time, of cross-sectional standard deviations in GDP (levels and per capita).

The reason for considering the average, over time, of cross-sectional deviations in income as a way verify if the cointegration results in table 12 are a result of the Balassa-Samuelson effect is as follows. A group of countries whose income levels move together over time, rather than diverge, should have a low, average of the cross-sectional standard deviation of income over time. Such a group of countries should be subject to the Balassa-

[6] I thank an anonymous referee for alerting me to the possibility of this effect as an explanation for my results.

Table 14: Correlations between the average over time of cross-sectional standard deviations of GDP (constant US$, 2005) and cointegration rates (Data source: the World Bank's *World Development Indicators*)

Country group or Currency Union	GDP per capita	GDP Level	Cointegration rate
NONE	12933.32	4.33×10^{12}	7.00
AUSTRALIA	16343.54	3.09×10^{11}	0.00
UEMOA	320.57	3.95×10^{09}	50.00
RAND	1190.31	1.99×10^{09}	33.33
CEMAC	3240.30	3.80×10^{09}	64.71
SINGAPORE-BRUNEI	9196.85	5.28×10^{10}	0.00
DOLLARIZED	18727.64	2.94×10^{12}	40.00
DENMARK	9052.41	1.37×10^{11}	0.00
INDIA-BHUTAN	281.12	4.51×10^{11}	0.00
ECCU	2413.93	1.73×10^{08}	36.67
EMU	16519.10	9.30×10^{11}	19.66
Correlation with the cointegration rate	-0.33	-0.19	

Samuelson effect and, consequently, should see their prices move closely over time or be cointegrated. In contrast, a group of countries with a strongly heterogeneous income profile over time should demonstrate weak co-movement of prices. Therefore, if the results in table 12 are a consequence of the Balassa-Samuelson effect instead of a measure of the extent of integration within the currency union, then the lower the average of cross-sectional standard deviations over time of income, the higher should be the frequency of cointegration within the currency union: a negative correlation.

The correlation between the averages over time of cross-sectional standard deviations and the rates of cointegration within currency unions is negative for both the level of GDP (-0.19) and GDP per capita (-0.33), findings consistent with the Balassa-Samuelson effect.

However, though the correlations may offer qualitative support to Balassa-Samuelson as an explanation for the results in tables 12 and 13, the quantitative magnitude of the correlations is particularly weak. Therefore, Balassa-Samuelson is an unlikely explanation for the finding that countries in currency unions have prices that move together over time in a way not found among countries that lack a common currency.

5 Conclusion

In order to understand better currency union operations, recent articles have suggested expanding the criteria for characterizing currency unions beyond the value of intra-union trade (Santos Silva and Tenreyro (2010)). This paper contributes to that discussion by examining price level movements in currency union member countries. More specifically, this paper tests whether price levels in member countries possess a common stochastic trend.

The trace statistic test for cointegration proposed by Johansen (1995) demonstrates that the price levels in most currency unions follow a common stochastic trend at the union-wide level. Although the union-wide results demonstrate the existence of a long-run and stable relationship among price levels, the nature of this relationship changes over time. A disaggregated, bilateral analysis generally confirms the multilateral analysis and indicates that non-trivial shares of individual country pairs within a currency union lack a common trend. The bilateral analysis is necessary to show that price convergence is a reliable, distinguishing feature of currency unions and not a trait peculiar to the individual countries within the union. The bilateral analysis also permits the use of longer lengths of data. Compared to the set of country pairs not in currency unions, the frequency is high. However, some unions such as the Eurozone and Rand zone have unexpectedly small shares of country pairs exhibiting cointegration.

When examining country pairs for a currency union where one country belongs to the union in question and one country does not, instances of a common stochastic trend are much rarer. Consequently, price level convergence, as indicated by cointegation, serves as a reliable metric to distinguish currency unions from other groups of countries. This pattern is not an idiosyncratic trait of the countries constituting the currency union (as indicated by the "partial" unions) but an attribute of the union itself.

These results provide an alternative metric to intra-union trade for gauging the extent of integration within a currency union. These results are unlikely to be a consequence of an unrelated phenomenon, such as the Balassa-Samuelson effect. The presence of a cointegrating vector indicates that the member countries of several currency unions are more integrated among themselves than are they with other countries. Left unanswered is why coefficients for the cointegrating vector would change in magnitude or signs depending on the time period analyzed. Future research will address this question.

Appendix: Currency unions and their composition

East Caribbean Currency Union (ECCU)

Antigua and Barbuda	Barbados (1965-1972)
Dominica	St. Kitts and Nevis
St. Lucia	St. Vincent and the Grenadines

West African Economic and Monetary Union (UEMOA)

Bénin	Burkina Faso
Côte d'Ivoire	Guinea-Bissau (1997-)
Mali	Mauritania (1960-1973)
Niger	Sénégal
Togo	

Communauté Économique et Monétaire de l'Afrique Centrale (CEMAC)

Cameroon	Central African Republic
Chad	Congo, Rep.
Equatorial Guinea (1985-)	Gabon
Madagascar (1960-1972)	

European Monetary Union (EMU) / Euroized

Austria (1999-)	Belgium (1999-)
Cyprus (2004-)	Estonia (2004-)
France (1999-)	Finland (1999-)
Germany (1999-)	Greece (2001-)
Ireland (1999-)	Italy (1999-)
Latvia (2005-)	Luxembourg (1999-)
Macedonia (2002-)	Malta (2005-)
Netherlands (1999-)	Portugal (1999-)
Slovak Republic (2006-)	Slovenia (2007-)
Spain (1999-)	

Dollarized countries

American Samoa	The Bahamas (1973-)
Bermuda	Ecuador (2000-)
El Salvador (2001-)	Guam
Liberia	Marshall Islands
Federated States of Micronesia	Northern Mariana Islands
Palau	Panama
Puerto Rico	Virgin Islands (U.S.)

Danish Krone zone

Denmark	Færoe Islands	Greenland

Australia zone

Australia	Kiribati	Tonga (until 1990)

Table 15: Cointegration and Granger causality results

Currency Union	**Country Pair (country 1 & country 2)**	**Cointegrated**	$\hat{\beta}_2^{\dagger}$	**Z-score for** $H_0 : \beta_2 = 0$	**Z-score for** $H_0 : \beta_2 = -1$	**Granger Causality**[*]
BENELUX	Luxembourg - Belgium	No				$\longleftarrow$
BENELUX	Netherlands - Luxembourg	No				$\longrightarrow$
CEMAC	Central African Republic - Cameroon	No				$\longleftrightarrow$
CEMAC	Chad - Cameroon	Yes	-1.104	-18.382	-1.725	$\longleftarrow$
CEMAC	Chad - Central African Republic	No				$\longrightarrow$
CEMAC	Congo, Republic of - Cameroon	Yes	-1.453	-23.003	-7.177	$\longleftarrow$
CEMAC	Congo, Republic of - Central African Republic	Yes	-1.105	-17.986	-1.714	$\longleftrightarrow$
CEMAC	Congo, Republic of - Chad	Yes	-1.326	-9.163	-2.251	$\longleftrightarrow$
CEMAC	Equatorial Guinea - Cameroon	Yes	-1.772	-24.02	-10.468	$\longleftrightarrow$
CEMAC	Equatorial Guinea - Central African Republic	Yes	-1.775	-24.568	-10.725	$\longrightarrow$
CEMAC	Equatorial Guinea - Chad	Yes	-1.51	-21.502	-7.265	$\longleftrightarrow$
CEMAC	Gabon - Cameroon	No				$\longrightarrow$
CEMAC	Gabon - Central African Republic	Yes	-0.776	-17.989	5.206	$\longleftarrow$
CEMAC	Gabon - Chad	Yes	-0.628	-16.398	9.723	$\longleftrightarrow$
CEMAC	Gabon - Congo, Republic of	Yes	-0.551	-18.187	14.834	$\longrightarrow$
CEMAC	Gabon - Equatorial Guinea	Yes	-0.411	-14.247	20.392	$\longleftarrow$
ECCU	Dominica - Anguilla	No				$\longrightarrow$
ECCU	Dominica - Antigua and Barbuda	No				$\longrightarrow$
ECCU	Grenada - Antigua and Barbuda	No				$\longleftarrow$
ECCU	Grenada - Dominica	No				$\longrightarrow$
ECCU	Montserrat - Antigua and Barbuda	Yes	-1.261	-58.643	-12.139	$\longleftrightarrow$
ECCU	St. Kitts and Nevis - Anguilla	Yes	-0.869	-35.828	5.384	$\longrightarrow$
ECCU	St. Kitts and Nevis - Dominica	Yes	-1.798	-14.909	-6.619	$\longrightarrow$
ECCU	St. Kitts and Nevis - Grenada	Yes	-1.319	-26.122	-6.32	$\longleftrightarrow$
ECCU	St. Lucia - Barbados	Yes	-2.197	-6.422	-3.499	$\longleftarrow$
ECCU	St. Lucia - Dominica	Yes	-1.592	-18.848	-7.007	$\longrightarrow$
ECCU	St. Lucia - Grenada	Yes	-1.312	-18.32	-4.354	$\longrightarrow$
ECCU	St. Lucia - St. Kitts and Nevis	Yes	-0.817	-16.256	3.629	$\longleftarrow$
ECCU	St. Vincent and the Grenadines - Anguilla	No				$\longrightarrow$
ECCU	St. Vincent and the Grenadines - Antigua and Barbuda	No				$\longleftarrow$

† Coefficient on country 1 normalized to 1

[*] The arrow's direction indicates which country's price level Granger causes the other country's price level. $\longleftrightarrow$ indicates bicausality.

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Table 15 – continued from previous page

Currency Union	Country Pair (country 1 & country 2)	Cointegrated	$\hat{\beta}_2^{\dagger}$	Z-score for $H_0 : \beta_2 = 0$	Z-score for $H_0 : \beta_2 = -1$	Granger Causality*
ECCU	St. Vincent and the Grenadines - Dominica	Yes	-1.57	-16.524	-6.002	None
ECCU	St. Vincent and the Grenadines - Grenada	Yes	-1.171	-23.141	-3.387	$\longrightarrow$
ECCU	St. Vincent and the Grenadines - St. Kitts and Nevis	Yes	-0.772	-28.093	8.308	$\longleftrightarrow$
ECCU	St. Vincent and the Grenadines - St. Lucia	No				$\longleftrightarrow$
EMU	Cyprus - Austria	No				$\longrightarrow$
EMU	Cyprus - Finland	Yes	-0.455	-4.948	5.933	$\longrightarrow$
EMU	Cyprus - France	No				$\longrightarrow$
EMU	Cyprus - Germany	Yes	-0.696	-4.148	1.815	$\longrightarrow$
EMU	Cyprus - Greece	No				$\longleftarrow$
EMU	Cyprus - Italy	Yes	-0.855	-16.612	2.808	$\longrightarrow$
EMU	Cyprus - Luxembourg	No				$\longrightarrow$
EMU	Cyprus - Netherlands	Yes	-0.8	-9.444	2.367	$\longrightarrow$
EMU	Cyprus - Portugal	No				$\longrightarrow$
EMU	Cyprus - San Marino	No				$\longrightarrow$
EMU	Cyprus - Spain	No				$\longrightarrow$
EMU	Finland - Austria	No				$\longrightarrow$
EMU	Finland - France	No				$\longleftarrow$
EMU	Finland - Germany	No				$\longrightarrow$
EMU	Finland - Netherlands	No				$\longleftarrow$
EMU	France - Belgium	No				$\longleftarrow$
EMU	Germany - Austria	No				$\longleftrightarrow$
EMU	Germany - France	No				$\longrightarrow$
EMU	Greece - Austria	Yes	-1.851	-21.936	-10.084	$\longleftrightarrow$
EMU	Greece - Belgium	No				$\longleftarrow$
EMU	Greece - Finland	No				$\longleftarrow$
EMU	Greece - Germany	No				$\longleftrightarrow$
EMU	Greece - Italy	No				$\longrightarrow$
EMU	Greece - Luxembourg	No				$\longleftrightarrow$
EMU	Greece - San Marino	No				$\longleftarrow$
EMU	Ireland - Belgium	No				$\longleftarrow$
EMU	Ireland - Finland	No				$\longleftarrow$

† Coefficient on country 1 normalized to 1

* The arrow's direction indicates which country's price level Granger causes the other country's price level. $\longleftrightarrow$ indicates bicausality.

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Table 15 – continued from previous page

Currency Union	**Country Pair (country 1 & country 2)**	**Cointegrated**	$\hat{\beta}_2^{\dagger}$	**Z-score for** $H_0 : \beta_2 = 0$	**Z-score for** $H_0 : \beta_2 = -1$	**Granger Causality***
EMU	Ireland - Germany	Yes	-0.306	-1.11	2.518	None
EMU	Ireland - Greece	No				$\longrightarrow$
EMU	Ireland - Italy	No				$\longleftarrow$
EMU	Ireland - San Marino	No				$\longleftarrow$
EMU	Italy - France	No				$\longrightarrow$
EMU	Italy - San Marino	No				$\longleftarrow$
EMU	Luxembourg - Germany	No				$\longleftrightarrow$
EMU	Luxembourg - Italy	No				$\longleftarrow$
EMU	Luxembourg - San Marino	No				$\longleftarrow$
EMU	Montenegro - Austria	No				$\longrightarrow$
EMU	Montenegro - Cyprus	Yes	-1.119	-18.358	-1.946	$\longleftarrow$
EMU	Montenegro - Germany	No				$\longrightarrow$
EMU	Montenegro - Ireland	Yes	-2.999	-7.168	-4.778	$\longleftarrow$
EMU	Montenegro - Italy	No				$\longrightarrow$
EMU	Montenegro - Netherlands	No				$\longrightarrow$
EMU	Netherlands - Italy	Yes	-0.846	-33.474	6.091	$\longleftarrow$
EMU	Netherlands - San Marino	No				$\longleftrightarrow$
EMU	Portugal - Belgium	No				$\longleftarrow$
EMU	Portugal - Germany	Yes	0.362	0.879	3.305	None
EMU	Portugal - Greece	No				$\longleftarrow$
EMU	Portugal - Ireland	No				$\longleftarrow$
EMU	Portugal - Italy	No				$\longleftarrow$
EMU	San Marino - France	No				$\longrightarrow$
EMU	Slovenia - Austria	Yes	-0.826	-13.489	2.838	$\longleftrightarrow$
EMU	Slovenia - Belgium	Yes	-0.82	-38.602	8.501	$\longleftarrow$
EMU	Slovenia - Finland	Yes	-0.868	-29.208	4.439	$\longleftarrow$
EMU	Slovenia - France	Yes	-1.274	-20.612	-4.438	$\longleftrightarrow$
EMU	Slovenia - Germany	Yes	-1.239	-17.526	-3.38	$\longleftarrow$
EMU	Slovenia - Greece	No				$\longleftarrow$
EMU	Slovenia - Italy	Yes	-0.884	-25.127	3.298	$\longleftarrow$
EMU	Slovenia - Luxembourg	Yes	-0.821	-15.323	3.34	$\longleftarrow$

† Coefficient on country 1 normalized to 1
* The arrow's direction indicates which country's price level Granger causes the other country's price level. $\longleftrightarrow$ indicates bicausality.

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Table 15 – continued from previous page

Currency Union	Country Pair (country 1 & country 2)	Cointegrated	$\hat{\beta}_2^{\dagger}$	Z-score for $H_0 : \beta_2 = 0$	Z-score for $H_0 : \beta_2 = -1$	Granger Causality*
EMU	Slovenia - Montenegro	No				$\longleftarrow$
EMU	Slovenia - Netherlands	Yes	-0.913	-13.172	1.257	$\longleftarrow$
EMU	Slovenia - Portugal	Yes	-0.993	-20.148	0.141	$\longleftarrow$
EMU	Slovenia - San Marino	No				$\longleftrightarrow$
EMU	Slovenia - Spain	Yes	-0.921	-22.965	1.976	$\longleftarrow$
EMU	Spain - Austria	Yes	-2.148	-11.882	-6.35	None
EMU	Spain - Belgium	Yes	-3.319	-6.65	-4.646	None
EMU	Spain - France	No				$\longleftrightarrow$
EMU	Spain - Germany	Yes	-3.568	-9.682	-6.968	None
EMU	Spain - Greece	No				$\longleftarrow$
EMU	Spain - Ireland	No				$\longleftrightarrow$
EMU	Spain - Portugal	No				$\longleftrightarrow$
INDIA-BHUTAN	India - Bhutan	No				$\longleftrightarrow$
SOUTH AFRICA	Namibia - South Africa	Yes	-1.033	-98.32	-3.132	$\longleftarrow$
SOUTH AFRICA	Swaziland - Namibia	Yes	-1.128	-113.264	-12.896	$\longrightarrow$
SOUTH AFRICA	Swaziland - South Africa	No				$\longleftrightarrow$
USA	Bahamas, The - Ecuador	Yes	-0.544	-51.786	43.402	$\longrightarrow$
USA	Bahamas, The - El Salvador	No				$\longrightarrow$
USA	Bahamas, The - Panama	Yes	-0.253	-0.943	2.792	$\longrightarrow$
USA	Bahamas, The - United States	No				$\longleftrightarrow$
USA	El Salvador - Dominican Republic	No				$\longrightarrow$
USA	El Salvador - Ecuador	Yes	-0.934	-16.127	1.147	$\longrightarrow$
USA	El Salvador - United States	No				$\longleftarrow$
USA	Liberia - Bahamas, The	Yes	-3.999	-38.647	-28.984	$\longleftarrow$
USA	Liberia - Ecuador	No				$\longrightarrow$
USA	Liberia - El Salvador	Yes	-2.591	-27.541	-16.913	$\longleftarrow$
USA	Liberia - Panama	Yes	-1.841	-10.987	-5.019	$\longrightarrow$
USA	Liberia - United States	Yes	-3.754	-33.093	-24.277	$\longleftarrow$
USA	Panama - Ecuador	Yes	-1.015	-32.472	-0.467	$\longleftrightarrow$
USA	Panama - El Salvador	Yes	-2.349	-9.442	-5.422	$\longleftarrow$
USA	Panama - Guatemala	Yes	-0.419	-5.602	7.776	$\longleftrightarrow$

† Coefficient on country 1 normalized to 1

* The arrow's direction indicates which country's price level Granger causes the other country's price level. $\longleftrightarrow$ indicates bicausality.

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Table 15 – continued from previous page

Currency Union	**Country Pair (country 1 & country 2)**	**Cointegrated**	$\hat{\beta}_2^{\dagger}$	**Z-score for** $H_0 : \beta_2 = 0$	**Z-score for** $H_0 : \beta_2 = -1$	**Granger Causality***
USA	Panama - United States	No				$\longleftarrow$
UEMOA	Burkina Faso - Benin	No				$\longrightarrow$
UEMOA	Burkina Faso - Cote d'Ivoire	Yes	-0.715	-67.245	26.851	$\longleftrightarrow$
UEMOA	Burkina Faso - Guinea-Bissau	Yes	-0.98	-24.463	0.497	$\longrightarrow$
UEMOA	Burkina Faso - Mali	Yes	-1.087	-51.225	-4.087	$\longleftrightarrow$
UEMOA	Burkina Faso - Senegal	No				$\longleftarrow$
UEMOA	Burkina Faso - Togo	Yes	-0.953	-28.747	1.419	$\longleftarrow$
UEMOA	Cote d'Ivoire - Benin	No				$\longleftarrow$
UEMOA	Cote d'Ivoire - Guinea-Bissau	No				$\longleftarrow$
UEMOA	Guinea-Bissau - Benin	Yes	-0.859	-32.679	5.382	$\longleftarrow$
UEMOA	Mali - Benin	No				$\longleftarrow$
UEMOA	Mali - Cote d'Ivoire	Yes	-0.728	-28.343	10.577	$\longleftrightarrow$
UEMOA	Mali - Guinea-Bissau	Yes	-0.926	-24.962	2.004	$\longleftrightarrow$
UEMOA	Niger - Benin	No				$\longrightarrow$
UEMOA	Niger - Cote d'Ivoire	No				$\longleftarrow$
UEMOA	Niger - Guinea-Bissau	Yes	-0.865	-22.958	3.593	$\longrightarrow$
UEMOA	Niger - Mali	Yes	-1.078	-30.607	-2.208	None
UEMOA	Senegal - Benin	No				$\longleftarrow$
UEMOA	Senegal - Cote d'Ivoire	No				$\longleftrightarrow$
UEMOA	Senegal - Guinea-Bissau	Yes	-0.774	-28.589	8.358	$\longrightarrow$
UEMOA	Senegal - Mali	Yes	-0.954	-46.877	2.276	$\longrightarrow$
UEMOA	Senegal - Niger	No				$\longleftrightarrow$
UEMOA	Togo - Benin	Yes	-0.871	-27.789	4.112	$\longleftarrow$
UEMOA	Togo - Cote d'Ivoire	No				$\longrightarrow$
UEMOA	Togo - Guinea-Bissau	Yes	-1.05	-21.352	-1.008	$\longleftrightarrow$
UEMOA	Togo - Mali	Yes	-1.14	-31.983	-3.922	$\longrightarrow$
UEMOA	Togo - Niger	No				$\longleftrightarrow$
UEMOA	Togo - Senegal	No				$\longleftrightarrow$

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