Classifying de facto exchange rate regimes of financially open and closed economies: A statistical approach

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Classifying *de facto* exchange rate regimes of financially open and closed economies: A statistical approach

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Abstract

This paper offers a new *de facto* exchange rate regime classification that draws on the strengths of three popular classifications. Its two hallmarks are the careful treatment of a nexus between exchange rate regime and financial openness and the use of formal statistical tools (the trimmed *k*-means and *k*-nearest neighbour methods). It is demonstrated that our strategy minimises the impact of differences between market-determined and official exchange rates on the 'fix' and 'float' categories. Moreover, it is more suited to assess empirical relevance of the Mundellian trilemma and 'irreconcilable duo' hypotheses. Using comparative analysis we find that the degree of agreement between classifications is moderate: the null of no association is strongly rejected, but its strength ranges from low to moderate. Moreover, it is shown that our classification is the most strongly associated with each of the other classifications and as such can be considered (closest to) a centre of a space of alternative classifications. Finally, we demonstrate that unlike other classifications, ours lends more support to the Mundellian trilemma than to the 'irreconcilable duo' hypothesis. Overall, our classification cannot be considered a variant of any other *de facto* classification. It is a genuinely new classification.

Keywords: *exchange rate regime; financial openness; macroeconomic trilemma; cluster analysis*

JEL Classification: F33, F31, C38, C82

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1. Introduction

The choice of an exchange rate regime is one of the focal issues in international macroeconomics. Suffice it to say that according to one of the prominent hypothesis, it was structural flaws of the interwar gold standard that made the Great Depression so severe and prolonged (Bernanke and James, 1991). More recently, Obstfeld and Rogoff (2000) explained that the exchange rate is 'the single most important relative price, one that potentially feeds back immediately into a large range of transactions.' In his survey paper Rose (2011, p 671) claimed, however, that 'such choices [of the exchange rate regime] often seem to have remarkably little consequence. Exchange rate regimes are flaky: eccentric and unreliable.' An intriguing example of such 'little consequence' was provided by Rey (2015/2018). She claimed that the choice of the exchange rate regime ceased to be important for countries with open capital accounts and the trilemma had been transformed into dilemma.

We think that the confusion about ramifications of exchange rate regime choices – at least part of it – stems from the difficulties economists encounter when they attempt to classify actual exchange rate regimes. On the one hand, Obstfeld and Rogoff (1995) argued that 'the spectacular expansion of world capital markets' made the fixed exchange rate a 'mirage.' On the other hand, Calvo and Reinhart (2002) discerned the 'fear of floating' syndrome. More generally, declared (*de jure*) and actual (*de facto*) exchange rate regimes could not be the same: using Levy-Yeyati and Sturzenegger's (2005) terminology 'words' do not necessarily match 'deeds.' Harms and Kretschmann (2009) argue that 'the confusing variety of results' concerning consequences of exchange rate regimes is due to the fact that alternative classification schemes reflect fundamentally different aspects of exchange rate policy. Official announcements ('words') can have different economic effects than the active exchange rate stabilization ('deeds') and yet different than *de facto* volatility of the relevant exchange rate ('outcomes').

The three well-known classifications of *de facto* exchange rate regimes were developed by the IMF, Reinhart and Rogoff (2004; in what follows RR) and Levy-Yeyati and Sturzenegger (2005; in what follows LYS).[1] The IMF's classification was based on officially reported arrangements till 1998. Starting in 1999 the IMF has adopted a hybrid approach: a country is classified in line with its declared exchange rate arrangement, if it is consistent with observed policies and outcomes.[2] In case of inconsistency, a country is classified by the IMF's staff on

[1] The IMF classification is updated in the *Annual Report on Exchange Arrangements and Exchange Restrictions*. The other two have recently been updated in Ilzetzki et al. (2017) and Levy-Yeyati and Sturzenegger (2016).
[2] For more on the evolution of categories used in the IMF's classification see, e.g., Klein and Shambaugh (2010, pp. 31-36) or Habermeier et al. (2009).

the basis of 'the observed behavior of the exchange rate, complemented by information on the monetary and foreign exchange policy actions taken by country authorities' (Habermeier et al., 2009). The RR classification is mainly based on the behaviour of a parallel exchange rate as it is considered 'a far better barometer of monetary policy than is the official exchange rate [… and …] is often the most economically meaningful rate' (Reinhart and Rogoff, 2004, p. 2). Two other important features of their approach are that they (i) use extensive chronologies of the history of exchange arrangements and related factors (exchange controls, currency reforms, anchor currencies); (ii) include a separate 'freely falling' category for countries whose annual inflation is above 40%. The LYS classification combines information on volatility of three variables: the level of the exchange rate, its changes, as well as foreign exchange reserves. The two distinguishing features of their approach are that they: (i) employ a statistical methodology to identify clusters of pegs, floats and intermediate regimes; (ii) allow for an 'inconclusive' category if volatilities examined are very low as the exchange rate and reserves stability may simply reflect an absence of shocks.[3]

The main contribution of this paper is that it offers a new *de facto* classification of exchange rate regimes that draws on the strengths of the three popular classifications. First, unlike many other classifications, the IMF's and LYS employ more data than just those on the nominal exchange rate. This is in line with Frankel and Wei's claim that 'judging a country's exchange rate regime […] by looking simply at variation in the exchange rate' is 'the folly' (Frankel and Wei, 2008, p. 390). Thus, we follow IMF's and LYS approach and use data on foreign reserves as well. Second, both the RR and LYS classifications allow for special categories that prevent unfounded or far-fetched precision. Our classification has the analogues of both 'freely falling' and 'inconclusive.' Interestingly, our 'under pressure' category – the analogue of the former – is identified with the algorithm employed and does not require additional data. As such it is robust to an objection raised by Harms and Kretschmann (2009) who claimed that a 'freely falling' category is 'problematic' due to the use of the arbitrary threshold of 40%. Third, economists have been rather economical with the employment of statistical tools to classify exchange rate regimes. Out of the well-known classifications only the LYS one is constructed with the usage of formal statistical methods (cluster analysis).[4] We borrow their idea, but come up with a substantially different

[3] Some other exchange rate regimes classifications include: a *de facto* classification (Bubula and Ötker-Robe, 2002), a 'consensus classification' (Ghosh et al., 2002), a bivariate classification (Shambaugh, 2004), a classification based on a 'regression method' (Bleaney and Tian, 2017).

[4] For a different approach based on statistical methodology see, e.g., Bleaney and Tian (2017). They, however, use simple regressions for the nominal exchange rates only.

classification strategy. There are three fundamental differences: (i) empirical standards of fixed and floating exchange rate regimes are derived from data for financially open economies only, whereas those that are financially closed are classified in subsequent steps in a way that does not distort those standards; (ii) the presence of outliers is tackled in a formal and impartial way, as we use the trimmed *k*-means method; (iii) no intermediate regimes are identified since empirical results provide little evidence of such a cluster.

Apart from the development of a new *de facto* exchange rate regime classification, we compare our classification with three other popular classifications developed by the IMF, RR and LYS. The three important findings can be summarised as follows. First, using formal statistical measures we confirm the finding of previous studies that the degree of agreement between alternative classifications, including ours, is moderate, although classifications remain similar enough to make it possible to reject the null of no association between them.[5] Second, we carry out an array of pairwise comparisons of alternative classifications and show that ours is the closest counterpart to each of the remaining classifications. Thus, our classification can be considered – to put it vividly – (closest to) a centre of a space of alternative classifications. Third and most importantly, it is demonstrated that the split into financially open and closed economies – which is a hallmark of our classification – brings about several important empirical consequences. The most important one concerns the relation between the exchange rate regime and monetary independence: it is shown that unlike the LYS classification, ours lends more support to the Mundellian trilemma than to the 'irreconcilable duo' hypothesis. Additionally, these three findings imply that our classification cannot be considered a variant of any other classification. This, on second thoughts, is not so surprising given fundamental differences between our approach and other approaches.

The paper is structured as follows. Section 2 covers the details of empirical strategy used to construct the classification of exchange rate regimes. Statistical tools employed and data that underlie our classification are shortly discussed in Section 3. Empirical results that encompass construction of our classification and its comparison with the alternatives are reported in Section 4. Given the importance of financial openness in our classification, Section 5 explains empirical implications of classifying separately open and closed economies. Conclusions are presented in the final section.

[5] See, e.g., Eichengreen and Razo-Garcia (2013) or Klein and Shambaugh (2010).

2. Empirical strategy

Empirical strategy employed consists of seven steps: (1) identification of an anchor currency; (2) division of country-year observations into financially open and financially closed; (3) choice of classification variables and constrained standardization; (4) clustering of financially open country-years; (5) reclassification of 'inconclusives;' (6) classification of financially closed country-years; (7) supplementary reclassification.

Identification of an anchor currency

First, it is important to identify the anchor (reference) currency. In this step we followed the approach similar to that of Frankel and Xie (2010) and used regression analysis to estimate flexibility of exchange rates of a given currency against potential anchor currencies: the euro, Japanese yen, pound sterling and US dollar.

To formalize the choice of the anchor (reference) currency, we run the set of regressions of the form (cf. Frankel and Wei, 2008 and Frankel and Xie, 2010):[6]

$$\Delta \log H_t = \sum_i \beta_i \Delta \log X_{i,t} + \varepsilon_t \qquad (1)$$

where H_t is the exchange rate of a currency under consideration, $X_{i,t}$ is the exchange rate of potential anchor currency i, Δ is an operator of a monthly change, and ε_t is an error term. Following Frankel and Wei (1994), all exchange rates are against an 'outside' currency – the Swiss franc. The main anchor currencies are considered, i.e. the euro, Japanese yen, pound sterling and US dollar, but in some cases we also include the Australian dollar, South African rand, Indian rupee and SDR.[7] The regressions are run on three-year moving windows, i.e. for each country-year we use monthly data for a given year and two adjacent years in order to avoid spurious switches from one anchor currency to another and have enough degrees of freedom. The anchor currency was identified as the one with the coefficient closest to unity, if it was statistically significant. In many cases it was the coefficient with the highest *t*-statistics.

Division of country-year observations into financially open and financially closed

Second, the country-year observations were split into two groups with respect to the openness to capital flows. The rationale behind the split is threefold and the arguments are related to the

[6] We do not require coefficients to sum up to unity.
[7] This is a similar set to the one considered in the literature. See, e.g., RR (2004), LYS (2005).

Mundellian macroeconomic trilemma according to which a free movement of capital, the fixed exchange rate and autonomous monetary policy cannot be reconciled.[8]

Firstly, in a financially closed economy the exchange rate variability should, in principle, be lower than in an economy with an open capital account even if the monetary authority does not engage directly in the exchange rate stabilization. It is simply because a closed economy is insulated to a greater extent against shocks propagated via capital flows than an open economy. Thus, when trying to classify countries on the basis of empirical evidence on exchange rate variability one risks that the group of peggers will be dominated by financially closed countries whereas those that are financially open will be squeezed into the group of floaters. More formally, the choice of centroids around which the clusters were constructed and the partitioning into groups would be distorted in that sense that they would be driven by capital openness rather than the actual exchange rate regime.

Secondly, capital controls have more often than not been imposed to strengthen the monetary authority control over the exchange rate. The unintended consequence could be the emergence of a dual or parallel market. Reinhart and Rogoff (2004, p. 2) argued that 'any classification algorithm that fails to distinguish between unified rate systems (with one official exchange rate and no significant "black" or parallel market) and all others is fundamentally flawed' and based their classification on a dual or parallel exchange rate which they considered 'the most economically meaningful rate.' According to Shambaugh (2004), however, such an approach, merges information about barriers to capital flows and the exchange rate regime.[9] Our approach meets both challenges. On the one hand, we clearly distinguish between financial openness and the exchange rate regime and on the other hand the approach is free of a 'fundamental flaw' as the categories used in the classification are derived from the data for financially open economies, i.e. those in which disparities between market-determined and official exchange rates are not observed.

Thirdly, an important argument against the trilemma has been put forward by Rey (2015/2018, 2016). She claimed that '[w]henever capital is freely mobile, the global financial cycle constrains national monetary policies regardless of the exchange rate regime' (Rey, 2015/2018). Taking that argument seriously one should recognize that the issue of capital account openness could be a central one when trying to re-examine the importance of the exchange rate regime, especially for monetary autonomy.[10] Thus, it is the classification that is

[8] For a recent discussion of this trilemma (and others) see, e.g., Bordo and James (2017).
[9] Reinhart and Rogoff (2004) admitted that dual/parallel rates had been usually accompanied by exchange controls.
[10] See, e.g., Edwards (2015) for evidence from Latin American countries with flexible exchange rates.

built on the basis of data for countries which allow for free capital movement that seems the most appropriate in research on the validity of Rey's hypothesis *irrespective* of an a priori judgement on the hypothesis. In other words, empirically identified standards of both fixed and floating exchange rate regimes should be derived from observations for economies that are financially open. Otherwise, a comparative analysis of *de facto* exchange rate regimes, regardless of the results obtained, could be undermined with the argument that what was compared was not exchange rate regimes but capital account openness.

Choice of classification variables and constrained standardization

The third step of our strategy is the selection of variables used to construct the classification. It may seem natural to use data on the exchange rate variability when building the *de facto* exchange rate regime classification. In principle, such an approach underlies the two popular exchange rate classifications developed by RR and Shambaugh (2004).[11] An alternative approach has been adopted by LYS: they combined information about the variability exchange rate and variability of the foreign exchange reserves.[12] We find their approach appealing because of two reasons. Firstly, it fits well the definitions of fixed and floating exchange rate regimes that are used in the literature, because the activity of the monetary authorities in the foreign exchange market is considered a distinguishing feature of the regime.[13]

Secondly, an omission of information conveyed by the foreign exchange reserves variability can distort the classification. The focus on the exchange rate variability only results, in principle, in an identification of low and high variability objects. A mapping of low and high exchange rate variability objects into peggers and floaters, however, is not unambiguous. The problem is that the low-variability group comprises not only genuine peggers, but also floaters with stable exchange rates due to low exchange market pressure (EMP). The similar problem can be observed in the high-variability group. It includes not only genuine floaters, but also economies whose authorities heavily intervene in the foreign exchange market, e.g. in order to off-load high EMP, and thus cannot be considered floaters.

[11] See also the updated classification by Ilzetzki et al. (2017) and more recent classification by Klein and Shambaugh (2010).
[12] See also the updated classification in Levy-Yeyati and Sturzenegger (2016).
[13] For example Stevenson (2002a, p. 250) defined the fixed exchange rate regime as the one in which 'the authorities systematically intervene in the foreign exchange market, selling domestic currency and buying foreign exchange when there is excess demand for domestic currency on the foreign exchange market, and vice versa.' A flexible exchange rate regime is a monetary framework in which 'the authorities do not intervene in the foreign exchange market to peg the exchange rate' and 'supply and demand in the foreign exchange market determine the exchange rate' (Stevenson, 2002b, p. 259).

Additional information about foreign exchange reserves is useful in both cases as it allows to refine the classification by separation of peggers from country-years that are inconclusive (low EMP) and floaters from countries that are subject to foreign exchange market turbulences (high EMP).

Klein and Shambaugh (2010, p. 41), however, are rather sceptical about using data on foreign exchange reserves variability. Their point is that on the one hand the exchange rate stability does not require changing reserves if a country is willing to change its money supply or interest rates, and on the other hand changes in reserves may not be related to concrete commitment to the exchange rate peg if all intervention is sterilized. Their line of reasoning is sound, albeit its implications for applied work is rather limited as no alternative solution to the problems discussed above has been offered. The implication is that even two variables are not enough to uncover the exchange rate regime and the additional data on interest rates should be used.

The problem raised by Klein and Shambaugh (2010) is not a new one. According to Tavlas et al. (2008, p. 949) '[m]ovements in interest rates (as well as other, less-conventional types of intervention) are the dog-that-did-not-bark variable of *de facto* codings based on statistical algorithms.' They explain, however, that the primary reason to leave out the interest rate is the lack of comprehensive and reliable interest rate series for many economies over long time.

It seems that the use of some measure of interest rate co-movements to construct the exchange-rate classification can be jeopardized by an additional conceptual problem: although an inclusion of the rate of interest fits well to the framework of macroeconomic trilemma, it is not quite clear how the knowledge of the behaviour of interest rate differential could be used to separate fixed and floating exchange rate regimes on empirical ground. Admittedly, one can claim that a low variability of the interest rate differential is characteristic for a fixed exchange rate and high for a floating rate. This, however, is true only in tranquil times. When the risk premium jumps the opposite pattern can be observed: a pegger can defend the exchange rate with a rise in the interest rate, so the differential will become more volatile – this is indeed the case Klein and Shambaugh (2010) refer to – whereas a floater can rely on the exchange rate adjustment, so the interest rate differential can remain relatively stable.[14] Moreover, even in tranquil times there can be not too much difference between peggers and floaters with respect to the behaviour of the interest rate differential, because a central bank

[14] See, e.g., Dąbrowski et al. (2015) who identified the actual variant of monetary policy adopted in response to the global financial crisis and provided empirical evidence that the crisis resilience of emerging market economies was not determined by the exchange rate regime *per se* but by the actual variant of monetary policy.

may be willing to include external financial developments in its policy reaction function. This point was raised by Disyatat and Rungcharoenkitkul (2016, p. 214) who noted that the association between monetary autonomy and observed interest rate co-movements neglects the 'distinction between the *ability* to set monetary policy independently and the *willingness* to do so' (emphasis in the original). Thus, the degree to which a domestic interest rate vary with a foreign one can be used to assess monetary dependence, but not monetary autonomy, much less the exchange rate regime.

The arguments we referred to above illustrate that the choice of classification variables is not straightforward. In our opinion, however, relaying on exchange rate series exclusively is an inferior strategy, especially when using a statistical algorithm, mainly because it rises the risk of distorting the correspondence between intended categories of fixed and floating exchange rate regimes and the clusters actually obtained. Taking into account both exchange rate and foreign exchange reserves series counteracts that risk but leaves us with two additional categories beyond fixed and floating rate regimes, i.e. 'inconclusive' and 'under pressure.' Our choice can, therefore, be considered conservative as it prevents us from being unduly uncompromised in the search for peggers and floaters and forces to recognize the ambiguous cases.

Two measures of variability are used as classification variables. One is the average absolute monthly percentage change over the year *t* and is defined as

$$\mathrm{var}_{1,t}(x) = \frac{1}{12}\sum_{m=1}^{12}\left|\frac{x_m - x_{m-1}}{x_{m-1}}\right| \tag{2}$$

where x is the level of the exchange rate against the anchor currency or the level of the foreign exchange reserves. Another measure of variability is the standard deviation of monthly percentage changes in the year *t* defined as

$$\mathrm{var}_{2,t}(\Delta x) = \sqrt{\frac{1}{12}\sum_{m=1}^{12}\left(\Delta x_m - \overline{\Delta x}_t\right)^2} \tag{3}$$

where Δx is the percentage change in the exchange rate against the anchor currency or the percentage change in the foreign exchange reserves. The average monthly percentage change over the year *t* is denoted with a bar.

Having obtained four classification variables we standardized them in order to avoid the risk of relying excessively on a single variable (see, e.g., Mohamad and Usman, 2013). The standardization was constrained in two ways. At this stage – due to the reasons explained above – we focused only on the country-year observations that were found to be financially

open. Moreover, standardization was carried out for each year separately. The reason behind that constraint was that the behaviour of both peggers and floaters is very likely to be quite different in the years of financial turbulences and in periods of tranquillity in the global economy. Thus, without such a constraint one risks that the algorithm would be oversensitive to differences between country-years that are driven by global financial conditions rather than by actual exchange rate regimes.

Clustering of financially open country-years

In the fourth step the cluster analysis technique is employed to detect homogeneous groups of country-year observations. As our objective is to construct *de facto* classification, i.e. the one which is derived from the actual behaviour of monetary authorities, the natural choice is the unsupervised learning algorithm such as the *k*-means method. Like other statistical clustering methods it allows to partition a large set of objects into groups that are internally homogenous. The basic idea behind the *k*-means method is to define *k* centroids, each of which – to put it informally – can be considered the centre of one of *k* groups, and then associate each data point to the nearest centroid. The main advantage of the method is that centroids are not imposed by a researcher but are iteratively identified within the algorithm.[15]

There are two important empirical problems that plague the *k*-means method. First, the number of groups, *k*, is set a priori rather than determined by the algorithm, so the composition of clusters can change as their number is altered. Second, the location of centroids can be distorted by outlying observations. It is not hard to imagine that even a single outlier, provided that it is indeed very different from other data points, can constitute a separate cluster. Since the number of clusters is fixed a priori, other data points need to be squeezed in the remaining $k-1$ clusters. Such a partitioning would be quite different from the one in which there are *k* clusters and the outlier is simply omitted.

The theory of exchange rate regimes can be used to overcome the first problem. There are two standards of exchange rate regime: the fixed rate regime and the floating rate regime. The theory implies that the accommodation to shocks results in high foreign exchange reserves variability in the former regime as monetary authorities stabilize the exchange rate. The opposite pattern holds in the latter regime, since monetary authorities refrain from foreign exchange market interventions and allow the exchange rate to adjust. One, however, should not exclude a priori two other possibilities, i.e. the cases in which variability of *both* variables is either low or high. We label these two groups 'inconclusive' and 'under pressure,'

[15] The *k*-means algorithm is explained in more detail below.

respectively and reconsider them in the subsequent steps of our strategy. The point is that the number of groups can be justified by economic considerations.

In order to minimise the risk involved in the choice of *k* the statistical measure of the quality of partitioning such as the average silhouette can be employed. It is a joint measure of cohesion and separation of clusters (Rousseeuw, 1987). The silhouette is calculated for each observation and ranges from -1 to +1. The high value of silhouette indicates that a given object is well-matched to its own cluster and poorly matched to neighbouring clusters. The average value of silhouette shows accuracy of the clustering configuration. Small values of the average silhouette might indicate that number of cluster used is inappropriate. We use that measure to check if the theory-based choice of *k* fits the data.

The presence of outliers can be remedied with 'impartial trimming,' i.e. self-determined by the data, procedure that was proposed by Cuesta-Albertos et al. (1997) (see also Gallegos, 2002). The trimmed *k*-means method they developed allows for removing a certain fraction of the 'most outlying' data points. The important point to emphasize is that outliers are not trimmed mechanically, i.e. by an elimination of a certain fraction of upper (or lower) tail of data points for each of the classification variables, but are identified as the most distant from centroids. The important implication is that 'impartial trimming' allows to consider outliers data points that lie between clusters, which, by definition, is not possible under mechanical trimming.[16] The explicit and objective treatment of outliers makes the trimmed *k*-means method more robust than a standard *k*-means method.

The way these two problems are solved is an important difference between our approach and the one applied by LYS. As far as the first problem is concerned they also relied on the theory, but considered the cluster with high variability of both the exchange rate and reserves as the one corresponding to the intermediate exchange rate regime.[17] To us, such a group includes countries that were under strong foreign exchange market pressure (if not in an overt currency crisis) rather than countries that placidly managed their exchange rates. Unfortunately, LYS did not report any statistical measure for their choice of *k*.

While the differences in the number of groups can be justified by the lack of decisive argument, the differences with respect to the way the second problem has been dealt with seem to be easier to assess. LYS simply eliminated the two per cent upper tail of observations for each of the three classification variables and then applied the *k*-mean method. As

[16] The trimmed *k*-means algorithm is explained in more detail below.

[17] To be precise they distinguished between two intermediate regimes: 'crawling peg' and 'dirty float.' The former was identified as the one with high reserves variability, high exchange rate variability, but low volatility of exchange rate changes, whereas the latter was characterized by high variability of all three variables.

explained above such an approach is less efficient in elimination of truly relevant outliers and thus seems to be inferior from the statistical point of view to the trimmed *k*-means method, which is used in our approach.

Reclassification of 'inconclusives'

One of the clusters is expected to group observations with low variability of both exchange rate and foreign exchange reserves which are characteristic for calm times. That cluster includes country-years characterized by low exchange market pressure, i.e. cases in which there is no need for either exchange rate adjustment or foreign exchange interventions. Thus, following LYS, we called this group 'inconclusive.'

The problem with this group is that it hides both peggers and floaters which makes the classification incomplete from pragmatic point of view. LYS argued that the variability of the classification variables within the category 'inconclusive' can be exploited to unveil exchange rate regimes. Thus, following their line of reasoning we applied the ordinary *k*-means partitioning algorithm to that group (no trimming was called for as the outliers have already been eliminated in the previous step). This time, however, we set the number of groups to three and isolated peggers, floaters and 'deep inconclusives.' We have not allowed for the fourth category, because it would be unreasonable to attempt to identify the cases 'under pressure' in the group that in the previous step has been found to share low exchange market pressure.

Classification of financially closed country-years

The sixth step of our strategy deals with the country-year observations that were considered closed to capital flows and left aside. The reason for excluding them from the previous steps was to avoid an undesired impact on the partitioning, in particular the location of centroids, stemming from the relatively low capital account openness (see step two). The classification of data points corresponding to low financial openness is based on the similarity between a given data point and the categories identified for the financially open country-years. In principle, we search for the category to which a given financially closed country-year is the closest.

In this step we employ the *k*-nearest neighbour method. It consists in finding the *k* nearest objects in some reference set and taking a majority vote among the classes of these *k* objects. The clusters obtained in the fourth step were used as the reference set and thus a country that

was closed to capital flows in a given year was classified to the most frequently represented category in the nearest neighbourhood.

We applied the *k*-nearest neighbour method in a way that was symmetric to the clustering analysis in the previous steps, i.e. we allowed financially closed country-years to be classified not only into groups of peggers and floaters, but also into three remaining categories: 'inconclusive,' 'under pressure' and outliers.

Supplementary reclassification

The last step is motivated by the similar concern to the one behind the reclassification of 'inconclusives,' that is the concern about the completeness of classification. The trade-off is between statistical justification and completeness of the results. So far we have given the priority to statistical considerations – even in step five which was oriented at making the classification more useful from pragmatic point of view we followed the statistical algorithm. In the last step we abandon purely statistical approach and inspect the categories that potentially hide peggers and floaters, i.e. 'inconclusive,' 'under pressure' and outliers.

Three explicit reclassifying criteria are adopted in order to control the arbitrariness of the procedure: (1) when the average absolute monthly change in the exchange rate in a given year is less than 0.01%, a country is considered to peg its currency in that year; (2) a country 'under pressure' is reclassified as a pegger (floater) in a given year if in the two adjacent years it pegged (floated) its currency and (3) countries that joined the euro area are considered peggers starting the year of the euro adoption. As far as the first criterion is concerned we are rather conservative in the choice of the ceiling for exchange rate variability. Suffice it to say that some authors consider the two-per cent deviations from the central parity as consistent with the fixed exchange rate regime (see, e.g., Shambaugh, 2004). The annual deviations allowed for by the ceiling we selected would be 0.12%, which is much less than the two-per cent rule. Reclassification carried out under the second criterion is conditional on the results obtained with the *k*-means methods in the previous steps in that sense that it requires the country to be uniformly classified in the group of either peggers or floaters in the year before and the year after the one in which it has been found to be 'under pressure.' The special treatment of the euro area member states can be justified with the irrevocably fixed

conversion rates of national currencies into euro and transferring the control over monetary policy to the supranational institution, i.e. the European Central Bank.[18]

Moreover, to increase the transparency of our strategy we present the classification in such a way that it is easy to recover the impact of the step considered on final results. Thus, the results obtained with the use of the full procedure, as well as those obtained with the procedure that excludes the last step are reported.

3. Statistical tools and data description

Clustering methods

Statistical clustering methods are dedicated to detect homogeneous groups out of heterogeneous large samples. Ideally, the groups should be homogeneous and the differences between them as large as possible (see, e.g., Kaufman and Rousseeuw, 1990). One of the most frequently used clustering algorithms is the *k*-means method. The notion of the *k*-means method is to partition a given sample $\{x_1,...,x_n\}$ into *k* clusters by solving the minimization problem:

$$\arg \min_{m_1,...m_k} \sum_{i=1}^{n} \min_{j=1,...k} \| x_i - m_j \|^2 \qquad (4)$$

where $\{m_1,...,m_k\}$ are *k* point centres. All observations are assigned to the closest centres and then the new centres, centroids of the groups are determined. The procedure (relocation) is carried out as long as there is no single object which changes clusters.

One of the main problems of *k*-means is the lack of robustness in samples with outlier observations (García-Escudero et al., 2010). The *k*-means algorithm has a breakdown point equal to zero (see García-Escudero and Gordaliza, 1999), which means that even a single outlier is able to completely distort the results obtained with that method.

In order to overcome that problem the trimmed *k*-means method has been proposed. The trimming means that an α-portion of the most outlying observations are removed. It has to be stressed, however, that in a multivariate case, a natural geometrical order does not exist, and outliers cannot be seen as the 'largest' or 'smallest' observations. Removing observations which are extreme in a particular (single) dimension is not an optimal strategy as 'bridge points' lying between clusters could not be eliminated and the clustering results could be distorted.

[18] Inclusion of the euro area member states in the group of peggers is consistent with the lack of separate (national) legal tender. The IMF, however, classifies the European Monetary Union as 'free floating' on the basis of 'the behavior of the common currency' (IMF, 2007).

The trimmed *k*-means algorithm searches for *k* cluster centres $\{m_1,...,m_k\}$ which is done by solving the double minimization problem:

$$\arg\min_{Y} \min_{m_1,...,m_k} \sum_{x_i \in Y} \min_{j=1,...,k} \| x_i - m_j \|^2 \qquad (5)$$

where *Y*'s are subsets of size $n(1-\alpha)$ taken from the sample $\{x_1,...,x_n\}$. As a result a proportion α of observations (outliers) is left unassigned.

The algorithm of trimmed *k*-means consists of following steps (García-Escudero et al. 2010):

1. Random step: *k* initial centres $\{m_1^0,...,m_k^0\}$ are chosen randomly.
2. Concentration step:
   - 2.1 Keep the set *H* made of the $n(1-\alpha)$ observations closest to the centres $\{m_1^l,...,m_k^l\}$.
   - 2.2 Partition *H* onto *k* subsets $\{H_1,..., H_k\}$, where H_j contains the observations in *H* closer to the centre m_j^l than to the other centres.
   - 2.3 Update the centres $m_1^{l+1},..., m_1^{l+k}$ such that each centre m_j^{l+1} is the sample mean of the observations in H_j.
3. Repeat Step 1 and Step 2 several times and keep the solution which minimize the objective function given in (5).

Classification with the k-nearest neighbours method

The aim of classification based on the *k*-nearest neighbours method is to predict the category or class of objects. It is necessary, however, to start with a set of data which classes are already known. Such a set is called a training set. Then, the properties of a new object are compared with the properties of objects in different classes. Finally, the new object is classified to the class which contains objects most similar to the new one.

There are parametric and nonparametric classification methods. The first group encloses discrimination functions which require multivariate normality in particular classes (Welch's optional rule, see Rencher 2003, p. 314). The second group includes (among others) density estimation method, nearest neighbour method, classification trees method. The earliest nonparametric classification method is *k*-nearest neighbour rule proposed by Fix and Hodges (1951). The general idea is to classify a new object using information from its nearest neighbour. Despite its simplicity the *k*-nearest neighbours method demonstrated its power in a

number of real domains (Kotsiantis, 2007). The algorithm of the *k*-nearest neighbours consists of four steps:

1. A positive integer *k* is specified, along with a new sample.
2. *k* new entries in the training set, which are closest (statistical distance is used to measure the distance) to the new sample, are selected.
3. The most common classification of the entries is determined.
4. The new sample is classified to the category determined in Step 3.

In order to choose the value of *k*, it is recommended to try several values of *k* and to use one with the lowest error rate. Such an exercise is made within a training set.

Data description

The sample covers 183 countries in years 1995-2014, i.e. 3,660 country-year observations. The classification is based on five variables: capital openness index (developed by Chinn and Ito, 2006), two measures of exchange rate variability (the average absolute monthly change and standard deviation of monthly change), and two measures of foreign exchange reserves variability (the average absolute monthly change and standard deviation of monthly change). For data description and sources see Table 1. Due to limited data availability the sample included 3,068 observations.

Table 1. Description of underlying variables

Symbol	Name	Description	Source
KAO	Capital account openness	The Chinn-Ito index	The updated database developed by Chinn and Ito (2006, 2008)
EA	Exchange rate variability I	The average absolute monthly change in the exchange rate against an anchor currency	Authors' calculations based on data from the IMF
EO	Exchange rate variability II	The standard deviation of monthly change in the exchange rate against an anchor currency	Authors' calculations based on data from the IMF
RA	FX reserves variability I	The average absolute monthly change of foreign exchange reserves	Authors' calculations based on data from the IMF
RO	FX reserves variability II	The standard deviation of monthly change of foreign exchange reserves	Authors' calculations based on data from the IMF

Source: Authors' compilation.

4. Empirical results

New classification

The first step of our strategy is the identification of the reference currency, i.e. the one which is the anchor for the domestic currency. The step is important, witness the example of exchange rates of the Danish krone illustrated in Figure A1 in the appendix. The choice of the exchange rate against the US dollar (or the nominal effective exchange rate which is not depicted) would result in a misleading finding that Denmark adopted a floating rate. If instead the euro/ECU is selected as the anchor currency, the opposite conclusion seems justified.

The examination of monthly exchange rates resulted in finding that the US dollar was by far the most prevalent reference currency – its 'share' was above 63% (see Table A1 in the appendix). The euro was found to be an anchor currency for slightly fewer than 30% of country-year observations. In eight cases a different currency was identified as a reference currency: the Australian dollar for Kiribati, the South African rand for Botswana, Lesotho, Namibia, Swaziland, the Indian rupee for Bhutan, and the SDR for Libya and Myanmar. Four cases of a switch from one currency to another were observed in our sample: Algeria switched in 2003 from the euro to the US dollar, Lithuania and Sao Tome and Principe switched from the US dollar to the euro in 2002 and 2008, respectively, and Latvia switched from the SDR to the euro in 2005.

Ilzetzki et al. (2017) stressed that the distinguishing feature of their approach was that it placed 'considerable emphasis on getting the currency anchor right.' Thus, the anchor classification found with our algorithm was compared with anchor currencies identified by Ilzetzki et al. (2017).[19] The common set of countries included 181 countries over 1995-2015 period.[20] The simple measure of agreement between these two anchor classifications, i.e. the percentage of country-years with the same anchor currency across both classifications, was 84.7%. Less than perfect agreement was mainly driven by two reasons. First, Ilzetzki et al. (2017) did not identified an anchor currency for the cases labelled 'freely falling.' Second, they found that in the late 1990s some countries used the French franc and German mark as

[19] Their 'process of anchor currency selection' is different than ours. In principle, they rely on the monthly, one-year moving average of the absolute value of the change in the bilateral exchange rates relative to all candidate anchor currencies (Ilzetzki et al. 2017, pp. 9-13).

[20] Due to data availability we were unable to estimate an anchor currency for 14 countries that were included in the set of countries used by Ilzetzki et al. (2017). These countries are very small, e.g. Andorra, Liechtenstein, Palau, Tuvalu, or/and the data are of poor quality (if available at all), e.g. Somalia, Turkmenistan, Uzbekistan, Zimbabwe.

anchor currencies, whereas in our approach the ECU/euro was used.[21] If we made corrections for both differences, the agreement is stronger, 93.1%.[22] Thus, in spite of the fact that the different algorithms were in use, our results seem to be well in line with those obtained by Ilzetzki et al. (2017). This finding can be considered good news since the alternative approaches lend support one to another.

In the second step we use the index of openness to capital flows developed by Chinn and Ito (2006 and 2008) to separate financially open economies from those that are relatively closed. The index is based on the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER)* and takes into account four factors: the presence of multiple exchange rates, restrictions on current account, restrictions on capital account transactions, and the requirement of the surrender of export proceeds. The index is constructed as the first (standardized) principal component of these variables and ranges from 0 to 1.[23] The histogram of the index based on data for 183 countries in 1995-2014 is depicted in Figure 1.

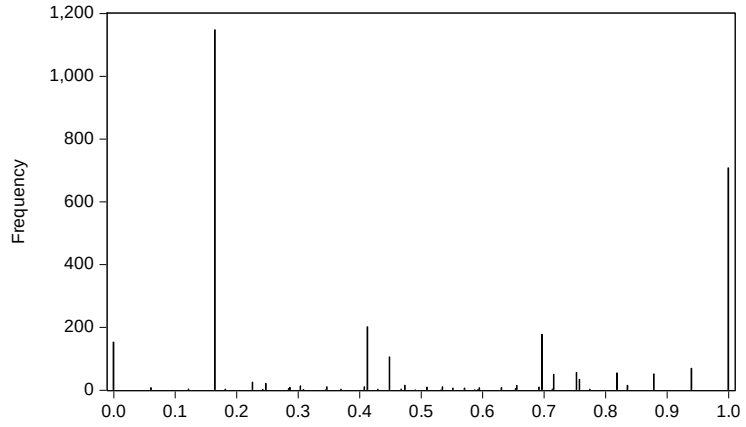


Figure 1. Capital account openness according to the Chinn-Ito index

Source: Authors' calculations based on data from Chinn and Ito (2006 and 2008).

There is no mechanical criterion of financial openness that can be used to split country-year observations into financially open and closed. One can, however, observe that there is a lot of country-years with an index of around 0.16 and – since it is a relatively low value – these should be definitely considered financially closed. The next numerous group of country-year observations is characterized by indices above 0.40. In order to avoid splitting relatively

[21] The third, minor reason of differences was that Ilzetzki et al. (2017) used the *domestic* currency as an anchor for some countries (Australia, Japan, the United Kingdom, the United States). We cannot follow that approach since our objective is to identify the relevant exchange rate which by definition requires *two* currencies.

[22] If just one correction is introduced the agreement is also higher: 88.0% if the first correction is made and 89.7% if the second correction is made.

[23] For details see Chinn and Ito (2008).

similar country-years into different categories we took an advantage of the fact that there is just few observations with the index between 0.16 and 0.40 and used 0.40 as a threshold value. Country-years with an index below it are considered financially closed and those with an index equal or above the threshold are treated as financially open.

The data on exchange rates and foreign exchange reserves were used to construct the classification variables in the third step of the strategy. Only variables for financially open country-years were considered at this stage. Measures of exchange rate and reserves variability were standardized for each year separately.

In the fourth step of the strategy we used the trimmed *k*-means method to partition country-year observations into homogenous clusters. We made two choices: the number of clusters was set to four, and the fraction of observations to be trimmed was set to two per cent. The former choice was motivated by theoretical considerations: with basically two variables, i.e. exchange rate variability and reserves variability, out of which each can take a 'low' or 'high' value, one should expect four different clusters: 'low/low', 'low/high', 'high/low' and 'high/high' (see Table 2). The silhouette measure for four clusters was 0.54 and was only slightly lower than for three or two clusters (0.61 and 0.57, respectively). Less than four clusters, however, seemed to be rather difficult to justify from a logical point of view, as at least two categories would be merged or/and one category would remain empty. It would be also questionable from an economic point of view as unduly restrictive: LYS, for instance, had even five clusters (although they did not report any statistical measure for their choice).

Table 2. Expected clusters and classification criteria

		Foreign exchange reserves variability	
		Low	High
Exchange rate variability	Low	'Inconclusive'	Peg
	High	Float	'Under pressure'

Source: Authors' compilation.

In making the latter choice we used the fraction suggested by LYS. It should, however, be stressed that the way we trimmed outliers was different to the one adopted in their studies, i.e. mechanical elimination of outliers for each classification variable separately. We employed the trimmed *k*-means method which identifies the outliers with respect to the centroids and updates outliers in each iteration of the algorithm.

The results of cluster analysis for financially open country-years are illustrated in Figure 2. The axes represent the first two principal components: the first one corresponds to the variability of the exchange rate and the second one to the variability of foreign exchange reserves. After the identification of outliers (34 obs.), four groups were identified. Two of them are straightforward to decipher. Peggers (green crosses) experienced low exchange rate variability and above normal variability of foreign exchange reserves (308 obs.), whereas floaters (dark blue x's) had the opposite characteristics (389 obs.) (see Figure 3). Interestingly, we isolated the group of observations with even greater exchange rate variability than that characteristic for floaters and foreign reserves variability comparable to that characteristic for peggers (blue diamonds; 81 obs.). According to LYS – who obtained a similar cluster – such observations constitute a group of countries under intermediate exchange rate regimes (e.g. dirty float). It is more plausible, however, that the country-years included in that group experienced strong foreign exchange market pressure and in some cases even a currency crisis. Thus, classifying them as managing their exchange rates (the intermediate exchange rate regime) seems to be at odds with their actual behaviour. Moreover, one would expect the managed exchange rate to display on average lower variability than the freely floating rate. This is not the case here. Thus, contrary to LYS, we prefer to call this group 'under pressure.'

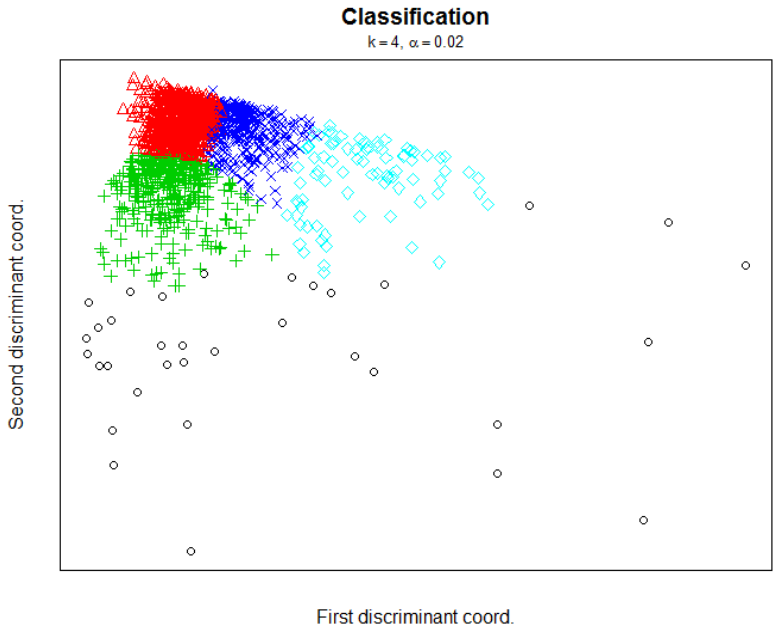


Figure 2. Clusters of financially open country-years
Notes: red triangle – 'inconclusive'; blue x – float; green cross – peg; light blue diamond – 'under pressure'; black circle – outlier.

The most numerous group (845 obs.) included country-year observations with below normal variability of both the exchange rate and foreign reserves. Such characteristics are displayed by both peggers and floaters in calm times. Thus, the group consists of 'inconclusives' (red triangles) and the question about its true composition remains open. The intended outcome of the fifth step of the strategy was to narrow down the degree of inconclusiveness. In order to do that we applied the simple *k*-means method (the outliers had been already excluded in the previous step) to divide this group into three categories: peggers (353 obs.), floaters (298 obs.) and 'deep inconclusives' (194 obs.). Their characteristics are reported in Figure 4. As expected, peggers and floaters are characterized by opposing variabilities of exchange rate and foreign exchange reserves, whereas 'deep inconclusives' experienced low variability of both classification variables.

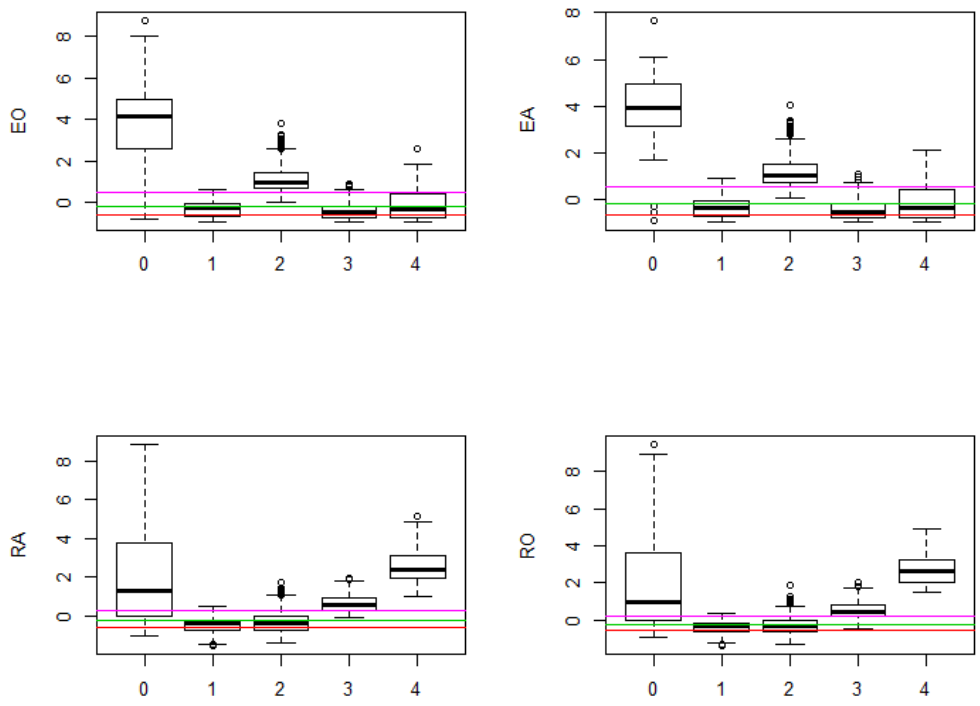


Figure 3. Exchange rate and FX reserves variabilities across groups identified in the first stage clustering

Notes: 0 – outlier; 1 – inconclusive; 2 – float; 3 – peg; 4 – 'under pressure.'
See also Table 1.

So far our strategy has been focused on financially open country-year which constitute 1,657 observations. The remaining 1,411 observations were on economies that were relatively closed to capital flows in some years. In the sixth step of the strategy we classified them with the *k*-nearest neighbour method. We tried from two to 20 neighbours and found out that the fraction of wrong classifications for a training set (created from financially open countries) was the lowest for 13 neighbours (see Figure 5, panel b). The difference between the classification based on 13 neighbours and those with a different number of neighbours, however, was rather small: the adjusted Rand index, that measures the agreement between classifications, was close to unity (see Figure 5, panel a). Thus, the parameter *k* was set to 13, and financially closed country-years were divided into peggers, floaters, 'inconclusives,' country-years 'under pressure' and outliers. The overall results of this and previous steps are reported in Table 3 in columns (3) and (4).

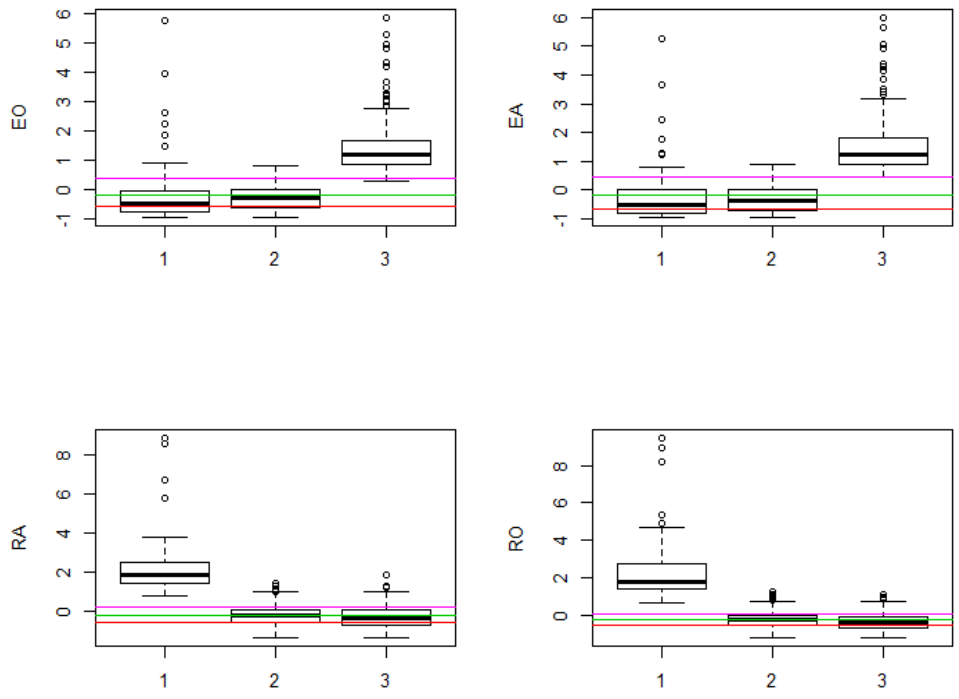
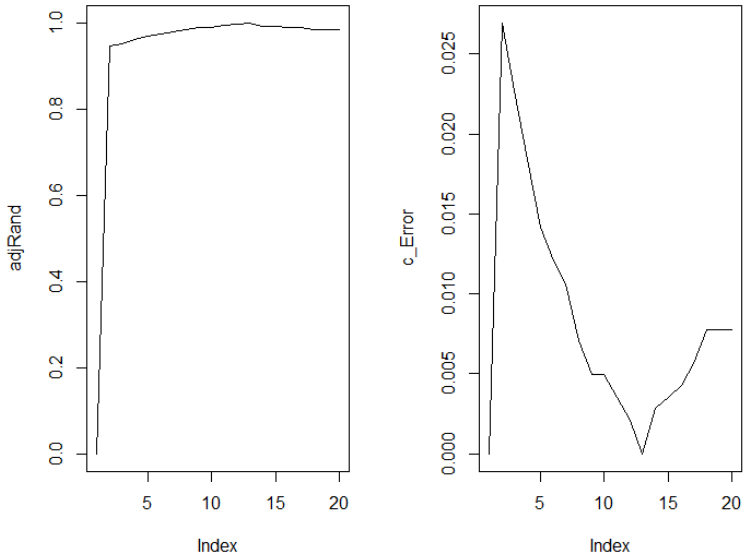


Figure 4. Exchange rate and FX reserves variabilities across groups identified in the second stage clustering

Notes: 1 – peg; 2 – 'deep inconclusive'; 3 – float. See also Table 1.



(a) Adjusted Rand index (b) Fraction of wrong classifications

Figure 5. Clustering with the *k*-nearest neighbour method – diagnostics
Note: The number of neighbours on the horizontal axes.

Table 3. Details of classification of exchange rate regimes

Category	**Financial openness***	**Classification after:**			
		Steps 1-6		**Step 7**	
(1)	(2)	(3)	(4)	(5)	(6)
Peg	open	1371	661	1879 (57.1%)	1008 (53.6%)
	closed		710		871 (61.7%)
Float	open	1035	687	1054 (32.0%)	699 (37.2%)
	closed		348		355 (25.2%)
'Under pressure'	open	262	81	76 (2.3%)	14 (0.7%)
	closed		181		62 (4.4%)
Inconclusive	open	280	194	182 (5.5%)	125 (6.6%)
	closed		86		57 (4.0%)
Outlier	open	120	34	100 (3.0%)	34 (1.8%)
	closed		86		66 (4.7%)
Total	open	3068	1657	3291 (100%)	1880 (100%)
	closed		1411		1411 (100%)

Note: * Financial openness defined with the Chinn-Ito index.

In the last step of the strategy we used three criteria to introduce modifications that increase the degree of completeness of classification. We moved 304 country-years from categories 'inconclusive,' 'under pressure' or outlier (altogether they include 662 obs., see column (3) in Table 3) to the groups of peggers (285 obs.) and floaters (19 obs.) if such a change was uncontroversial according to the three criteria adopted. First, the country-year was reclassified as a pegger if the average absolute monthly change of the exchange rate was less than 0.01% (230 obs.).[24] Such a criterion was motivated by the assumption that such small movements of the exchange rate throughout a year are very unlikely in a country with open capital account and floating exchange rate regime. Second, the country-year 'under pressure' was reclassified as a pegger (55 obs.) or a floater (19 obs.) if in the adjacent years it belonged to such a category. The rationale behind it was an observation that there is some inertia in the choice of the exchange rate regime, i.e. monetary authorities avoid too frequent changes of the exchange rate regime. Third, the country-years corresponding to the euro area member states were added to the group of peggers (223 obs.). These were not classified in the previous steps due to the lack of comparable data on foreign exchange reserves (after the euro adoption part of reserves is transferred to the ECB and reserves denominated in euro are no longer considered foreign exchange reserves).[25] Thus, the third criterion enabled us to limit the number of unclassified country-years due to the data availability (from 592 to 369 obs.). This is also the reason why the totals in columns (5) and (6) are greater than these in columns (3) and (4).

The final results are tabulated in columns (5) and (6) in Table 3. Overall, we identified more peggers (57.1%) than floaters (32.0%). This result was driven by a relatively low incidence of floating exchange rate regime (25.2%) and a high incidence of fixed rate arrangements (61.7%) in financially closed economies. In countries with open capital account the corresponding fractions were much closer to each other (37.2% and 53.6%, respectively). This finding is in line with the conjecture that can be derived from the macroeconomic trilemma: when capital flows are controlled, it is more attractive for the monetary authorities to maintain *de facto* fixed exchange rate as it does not require scarifying monetary autonomy.

Interestingly, the category 'under pressure' is more frequent when a country is financially closed (4.4% vs. 0.7%). This could be an indication that capital controls effectiveness is

[24] We tried less restrictive ceilings, i.e. 0.1%, 0.25% and 0.5%, and found that they allowed for reclassifying *additionally*, 38, 90 and 176 observations, respectively.
[25] See articles 30 and 48 of the Statute of the European System of Central Banks and of the European Central Bank (*Official Journal of the European Union*, 2016/C 202/01).

limited and that such barriers do not isolate an economy from the foreign exchange market pressure.

Comparative analysis

In order to shed more light on our classification, we compared it with other exchange rate regime classifications. Three popular classifications were taken into account. We considered the classification developed by LYS since in spite of many important differences we referred to above, their approach can be considered to be in the same class of approaches, i.e. those that are based on statistical methods. It was natural to take into account the classification tabulated by the IMF, because it is used in the literature as a kind of a reference point. A detailed work by RR on exchange rate arrangements with its emphasis on market vs. official exchange rates is also quite popular in the literature on international economics. Recently, Ilzetzki et al. (2017) have updated the RR classification and Levy-Yeyati and Sturzenegger (2016) have updated theirs.[26] Thus, we use these updates in the comparative analysis.

While examining the degree of agreement between alternative classifications, Klein and Shambaugh (2010, p. 47) transformed each classification to a dichotomous division into pegs and non-pegs and then, for each pair of classifications, calculated the percentage of observations that were classified in the same way. We followed a similar, although not exactly the same, way. We mapped alternative classifications into pegs and floats. In the RR classification hard and soft pegs were merged into pegs and intermediate regimes were combined with freely floating in a group of floats. The remaining two categories ('freely falling' and 'dual market in which parallel market data is missing') were treated as 'other.' In the LYS classification 'inconclusives,' some intermediate regimes (i.e. those identified in the second round of their procedure) and outliers were included in the category 'other.' In our classification an analogous rule was adopted – the difference was that instead of intermediate regimes the category 'under pressure' was included into 'other.' The details of mapping and sources are provided in Table 4.

[26] We thank Eduardo Levy-Yeyati and Federico Sturzenegger for making their updated classification available to us.

Table 4. Alternative exchange rate regime classifications

Classification*	No. of countries	Period	Mapping **	Source
LYS	183	1974-2013	Peg – Peg Crawling peg (1st round) – Peg Dirty float (1st round) – Float Float – Float Intermediate (2nd round) – Other Inconclusive – Other Outlier – Other	http://growthlab.cid.harvard.edu/files/growthlab/files/wp_319_v2.pdf and direct correspondence with Eduardo Levy-Yeyati
IMF	201	1970-2010	Hard peg (1) – Peg Soft peg (2) – Peg Intermediate (3) – Float Freely floating (4) – Float	http://www.carmenreinhart.com/data/browse-by-topic/topics/11/ (accessed on 13.07.2016)
RR	201	1940-2016	Hard peg (1) – Peg Soft peg (2) – Peg Intermediate (3) – Float Freely floating (4) – Float Freely falling (5) – Other Dual market in which parallel market data is missing (6) – Other	http://www.carmenreinhart.com/data/browse-by-topic/topics/11/ (accessed on 28.10.2017)
DPS	183	1995-2014	Peg – Peg Float – Float Inconclusive – Other 'Under pressure' – Other Outlier – Other	Authors

Notes: * LYS stands for Levy-Yeyati and Sturzenegger's (2016) classification, IMF for the International Monetary Fund's classification, RR for Ilzetzki et al.'s (2017) classification and DPS for classification by the authors; ** numbers in parenthesis in the RR and IMF classifications are 'the coarse classification codes.'

Source: Authors' compilation.

Table 5. New classification against the LYS classification, 1995-2013

		LYS Classification			
		Peg	**Float**	**Other** [b)]	**Total**
Our Classification	**Peg**	1037	336	325	1698
	Float	221	648	51	920
	Other [a)]	97	81	134	312
	Total	1355	1065	510	2930

Notes: [a)] Includes: 'inconclusives', 'under pressure' and outliers; [b)] Includes 'inconclusives' and intermediate regimes except for dirty floats and crawling pegs classified in the first round. The former included in 'float' and the latter in 'peg.'

Table 6. New classification against the RR classification, 1995-2014

		RR Classification			
		Peg	**Float**	**Other** [b)]	**Total**
Our Classification	**Peg**	1773	78	28	1879
	Float	469	542	43	1054
	Other [a)]	250	66	42	358
	Total	2492	686	113	3291

Notes: [a)] Includes: 'inconclusives', 'under pressure' and outliers; [b)] Includes 'freely falling' and 'dual market in which parallel market data is missing.'

Table 7. New classification against the IMF classification, 1995-2010

		IMF Classification			
		Peg	**Float**	**Other**	**Total**
Our Classification	**Peg**	827	465	.	1292
	Float	164	614	.	778
	Other [a)]	88	160	.	248
	Total	1079	1239	.	2318

Notes: a) Includes: 'inconclusives', 'under pressure' and outliers.

In Table 5 our classification is compared against the LYS one for the overlapping period of both classifications, i.e. 1995-2013. The degree of agreement can be traced out on the main diagonal, whereas off-diagonal elements correspond to divergence between classifications. For example, out of 1698 country-year observations recognized by our algorithm as pegs, 1037 were classified in the same way by LYS, which is more than 61.1%. The remaining observations were classified either as floats (336) or other (325) – the corresponding 'shares' were 19.8% and 19.1%, respectively. There was more agreement with respect to floats: more

than 70% of our floats were classified in the same category by LYS (648 out of 920). At the same time 221 floats can be found in a 'peg' category in the LYS classification (24.0%). Taking into account heterogeneity of the group labelled 'other' we do not expect too much agreement between classifications for this category. Indeed it is slightly more than 40%.

The comparison between our classification and the one developed by RR is depicted in Table 6. The common period covered by both classifications is from 1995 to 2014. The most striking finding is that almost all our pegs (94.4%) were classified in the same way by RR. The degree of agreement is rather poor in the group of floaters as many of them can be found in both peg (469) and float (542) categories in the RR classification (44.5% and 51.4%, respectively). Interestingly, we observe that quite a lot of country-years combined in the category 'other' (i.e. 'inconclusive', 'under pressure,' outlier) can be found in the RR classification in the group of peggers (250 out of 358 obs.).

In Table 7 our classification is tabulated against the IMF's classification. Comparison is over 1995-2010. Similarly to the comparison with the LYS classification we find more agreement between floats than pegs (78.9% vs. 64.0%). Contrary to the results obtained in comparison with the RR classification where the 'other' category was concentrated in the group of peggers (69.8%), here it can be found mainly in the group of floaters (64.5%).

The measure of overall agreement can be calculated as the number of observations on the main diagonal to the total number of observations (apparent correct classification rate). Using such a measure, we found out that our classification is the most similar to the RR classification (71.6%). Agreement with the two other classifications was smaller, but almost the same (about 62%).

We also applied alternative mapping to the one reported in Table 4. Following Klein and Shambaugh (2010) we used two alternative dichotomous divisions. One mapped categories into pegs and non-pegs and another one into floats and non-floats. The results are reported in Tables 8 and 9, respectively. Two general observations can be made. First, our classification is similar to the three others: the measure of overall agreement based on the fraction of the main diagonal elements to the total was found to range between 67.0% for the IMF's classification to 79.0% for the RR classification (both in the mapping into pegs and non-pegs). Second, there is more agreement between our classification and the three others with respect to the pegs than floats. It could be the result of stronger heterogeneity of alternative classifications with respect to the definition of the floating exchange rate regime than the definition of pegged rate regime. This can be observed in a large difference in the number of floats in alternative classifications: it ranged from 79 in the RR classification to around 1000

in the LYS classification and ours, whereas that of pegs is between 1197 in the LYS classification to around 1800 in our classification.[27]

Table 8. New classification against others under mapping into pegs and non-pegs

		LYS Classification (1995-2013)			**RR Classification (1995-2014)**			**IMF Classification (1995-2010)**		
		Peg	**Other**	**Total**	**Peg**	**Other**	**Total**	**Peg**	**Other**	**Total**
Our Class.	**Peg**	1028	670	1698	1325	554	1879	744	548	1292
	Other	169	1063	1232	138	1274	1412	218	808	1026
	Total	1197	1733	2930	1463	1828	3291	962	1356	2318

Table 9. New classification against others under mapping into floats and non-floats

		LYS Classification (1995-2013)			**RR Classification (1995-2014)**			**IMF Classification (1995-2010)**		
		Float	**Other**	**Total**	**Float**	**Other**	**Total**	**Float**	**Other**	**Total**
Our Class.	**Float**	639	281	920	68	986	1054	305	473	778
	Other	395	1615	2010	11	2226	2237	206	1334	1540
	Total	1034	1896	2930	79	3212	3291	511	1807	2318

Each exchange rate regime classification can be considered a set of nominal variables. The measure of overall agreement we used above to compare classifications is quite intuitive but rather a crude one. For example, it does not inform about statistical significance. Thus, we go beyond it and employ three other measures that were developed in statistics to describe the association between nominal variables: chi-square statistic, Cramér's V and Goodman and Kruskal's lambda statistic. The chi-square statistic is used to test whether two classifications are independent. The Cramér's V enables us to measure the strength of the association between classifications. It ranges from 0 to 1, with 0 indicating no association and 1 a perfect association. The strength of association can also be measured with Goodman and Kruskal's lambda statistic. It is a measure of proportional reduction in error in cross tabulation analysis

[27] The IMF's classification has not been taken into account here due to the shorter period it covers.

of two classifications (nominal variables). It also varies from 0 (no association) to 1 (a perfect association).

The results of association analysis for all six pairs of classifications and the baseline mapping (see Table 4 for details) are reported in Table 10. The results do not to depend on the pair under consideration and can be summarised as follows. First, the null of independence was strongly rejected (at 1% level of significance). Classifications, therefore, are related from the statistical point of view. Second, the strength of association is relatively moderate, as all its measures are far from 1. Third, our classification seems to be the most closely associated with each of the remaining classifications. For example, the highest Cramér's V for the pairs that involve the LYS classification was obtained for the pair that includes our classification. The same can be observed for other classifications, irrespective of the measure of strength of association applied. In other words, our classification can be treated as being closest to a centre of a space of alternative classifications. Fourth, the classification that is the most strongly associated with ours is the RR classification. It is a bit surprising since given some methodological affinity one could expect the strongest association with the LYS classification rather than with the RR one. This finding is important also because it demonstrates that the methodology we applied is different enough from that of LYS to bring in the classification that is more similar to the one developed by RR who did not employ the cluster analysis. Thus, our classification cannot be considered a variant of the LYS classification.

Table 10. Association measures: new classification vs. alternatives under baseline mapping

Classifications considered	Period considered	Pearson chi-square [a)]	Cramér's V [b)]	*Lambda* [b)]	Apparent correct classification rate
Our Class. vs LYS	1995-2013	820.2***	0.374	0.356	0.621
Our Class. vs RR	1995-2014	1,000.1***	0.398	0.250	0.716
Our Class. vs IMF	1995-2010	357.7***	0.393	0.243	0.621
LYS vs RR	1995-2013	201.1***	0.179	0.034	0.519
LYS vs IMF	1995-2010	240.0***	0.320	0.115	0.547
RR vs IMF	1995-2010	286.9***	0.340	0.130	0.591

Notes: [a)] The null hypothesis is that the two classifications are independent (no association); [b)] Cramér's V and lambda are measures ranging from 0 to 1 (the larger the value, the stronger the association).

The results for two other mappings are depicted in Tables A3 and A4 in the appendix. The general picture remains unchanged: all classifications are related, albeit the strength of association is moderate at best. The point about our classification being the closest associate for other classifications holds in general, although it is a bit weaker than under the baseline mapping.

5. Three arguments in favour of a new exchange rate regime classification

One of original features of our classification is that the categories of exchange rate regimes have been identified with the use of financially open country-year observations only. We raised three arguments based on the Mundellian trilemma in favour of such an approach: (1) the centroid which is relevant for the peg category is not distorted by low financial openness; (2) the differences between market-determined and official exchange rates are do not translate on the 'fix' and 'float' categories; (3) the classification is more useful in examining the relation between the exchange rate regime and monetary independence. The empirical implications of these three arguments are discussed below. In order to demonstrate their importance we focus on the differences between our classification and the LYS classification. The choice of the latter as a standard of comparison has been motivated by the fact that it is the closest to the former with respect to the methodology adopted. The important difference, however, is the treatment of financial openness.

In principle, capital controls contribute to exchange rate and foreign exchange reserves stability. Thus, the first argument implies that the exclusion of financially closed economies when constructing the standard of a fixed exchange rate regime should result in a relatively larger number of peggers than under the alternative approach. This implication is not too difficult to check. One can use the results on disagreement between classifications already presented in Table 8. There are 670 cases (23%) which our classification identifies as belonging to a 'peg' category and the LYS classification includes into other categories whereas there are only 169 cases (6%) classified in the opposite way.

The exchange rate regimes of the Baltic States in 2008-2010 can be used as an example here. All are financially open economies. Under the LYS classification a one-year shift towards a more flexible exchange rate regime was found in 2009: Latvia and Lithuania were classified as floaters and the crawling peg arrangement was identified in Estonia.[28] In our

[28] One should add that all these regimes were uncovered in the second round of clustering. Interestingly, in all three countries the exchange rate regime in 2008 was a less flexible one, i.e. a fixed exchange rate in Estonia, a dirty float in Latvia and a crawling peg in Lithuania. In 2010 the exchange rate regimes found were the same as those in 2008 (with the exception for Latvia for which there was a missing value in 2010).

classification all the Baltic States were uniformly classified as peggers in 2008-2010. One can find some support for our coding in the ECB *Convergence report*. Maximum percentage deviations from the ERM II central rate over the reference period (24 April 2008-23 April 2010) were -0.9% and 1.0% for Latvia and 0% for the two other Baltic States (ECB, 2010, pp. 106, 128, 146). It should be admitted, however, that the disagreement cannot be settled unambiguously. After all, both classification seek to uncover the *de facto* exchange rate regime. The point is rather that our classification leaves more room for a financially open economy to be classified as a pegger.

The second argument is related to the controversy over using 'black' market exchange rates. According to RR an important feature of an algorithm is to determine whether the exchange rate is unitary or not, whereas Shambaugh (2004) is sceptical and argues that such an approach merges information about capital controls (see Section 2 for details). Our approach meets both challenges as the categories are derived from the data for financially open economies and these rarely maintain non-unified exchange market.

In order to check the importance of this argument, we used the data on unitary exchange market index from Ilzetzki et al. (2017).[29] An index takes a value 1 if there are dual/multiple/parallel rates and 0 if the exchange rate is unified. Two points seem to be relevant in this context. First, the share of countries with non-unitary exchange rate decreased from 50% in the late 1980s to 25% in 1995 and was less than 15% on average in 1995-2014, which is the period covered by our classification.[30] Second, we found that the share of countries with non-unitary exchange rate in financially open economies, i.e. those that were used to construct fix and float categories, was 6.5%.[31] If we had neglected the division into financially open and closed economies, i.e. followed the approach of LYS, that share would be twice as large, 13.7%. The point is, therefore, that our approach insulates against potential distortionary effect of non-unitary exchange markets on classification results to a greater extent than the approach of LYS.

The third argument is related to the 'irreconcilable duo' hypothesis put forward by Rey (2015/2018). She claimed that national monetary policy was constrained by the global financial cycle if the country was financially open, no matter which exchange rate regime was adopted. Rather than testing that hypothesis directly – which is beyond the scope of this study and would require a separate, full-length paper – we focus on the nexus between monetary

[29] Data were obtained from Ethan Ilzetzki's website (accessed on July 18, 2018).
[30] Ilzetzki et al. (2017) observed, however, that that share increased to almost 20% in 2015 and 2016.
[31] Alternatively, one can observe that countries with dual/multiple/parallel exchange rate were those with relatively closed capital accounts. See Figure A2 in the appendix.

independence and the exchange rate regime in financially open economies. The extent of monetary independence is measured with an index developed by Aizneman et al. (2013). The index is based on the correlation between market interest rates and ranges from 0 (perfect dependence) to 1 (full independence).[32]

The distribution of monetary independence index in financially open economies, that is those for which the choice of the exchange rate regime does not matter according to the 'irreconcilable duo' hypothesis, can be useful in this context. We are interested whether the picture obtained under our classification is qualitatively different from the one obtained under the LYS classification. Figure 6 depicts the distribution of monetary independence index for floating exchange rate regime.[33] Both distributions look quite similar except for the relative frequency of cases with monetary independence index equal or close to zero. Under the LYS classification this relative frequency is very large, implying that in more than 22% of cases in which the floating exchange rate regime was found, there was virtually no monetary independence. This is not the case with our classification – there is not a single country-year with monetary independence equal to zero in the group of floaters and the relative frequency of cases close to zero is less than 0.8%.[34]

For the distribution of monetary independence index under the fixed exchange rate the opposite pattern can be observed in Figure 7. The very low values of monetary independence index are not too frequent under the LYS classification: the relative frequency of cases with the index close to zero is 4.5% (there is not a single observation with monetary independence equal to zero) which is surprisingly low in comparison to the case of floating exchange rate regime under the same classification. The distribution under our classification looks different: not only are cases with the index equal to zero observed, but the relative frequency of cases with the index equal or close to zero is 23.5%, which is five times more than under the LYS classification.[35, 36]

[32] Data were obtained from Hiro Ito's website (accessed on May 1, 2017).

[33] Only country-year observations present in both classifications are included in Figures 6 and 7. Thus, the differences between distributions are not due to the different coverage of country-years. Distributions without the correction for the common coverage look very much the same and are available upon request.

[34] Distributions of monetary independence index under floating exchange rate irrespective of the degree of openness to capital flows are presented in Figure A3 in the appendix. The results are similar to those in Figure 6.

[35] Distributions of monetary independence index under fixed exchange rate irrespective of the degree of openness to capital flows are presented in Figure A4 in the appendix. The results are similar to those in Figure 7.

[36] In order to check formally the similarity of distributions we have run the Wilcoxon and Mann-Whitney test of equality of medians. In all cases the null of equality was strongly rejected (at the 1% significance level). Detailed descriptive statistics and test results are depicted in Table A5 in the appendix.

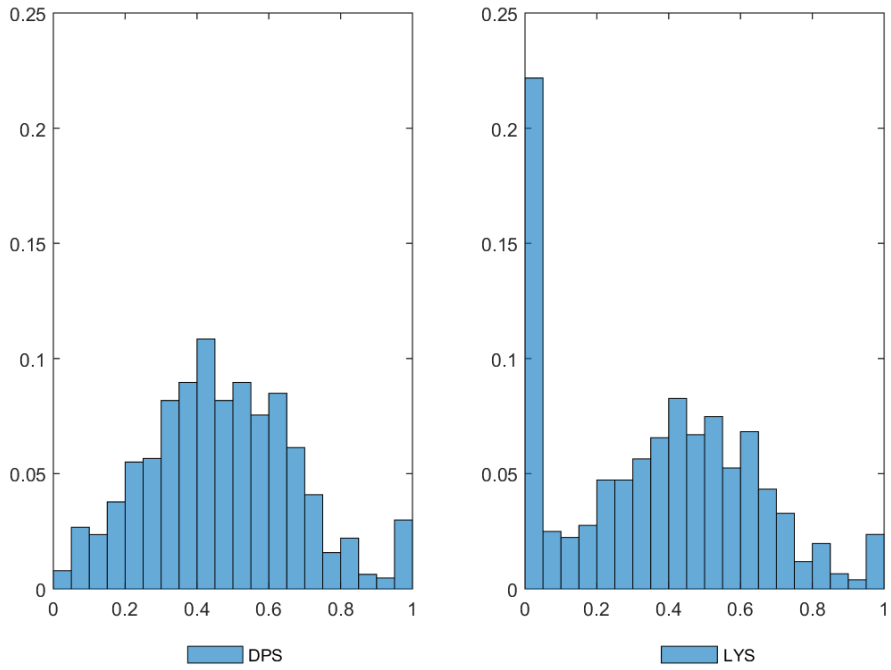


Figure 6. Distribution of monetary independence index under the floating exchange rate regime in financially open economies

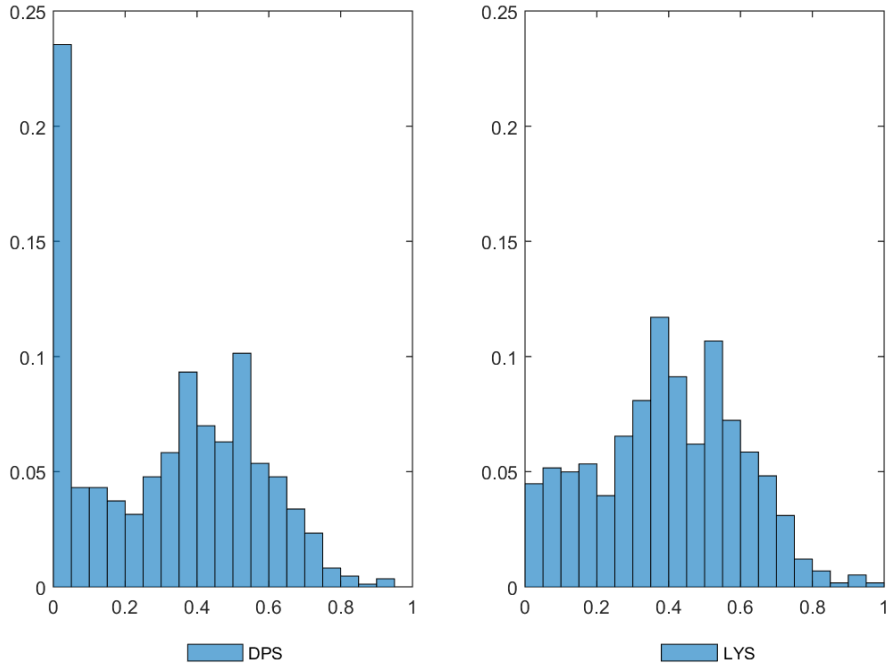


Figure 7. Distribution of monetary independence index under the fixed exchange rate regime in financially open economies

The results of this exercise demonstrate that taking into account capital account openness when building the exchange rate regime classification has important consequences. Not only is our classification different from the LYS classification, but these differences can feed into empirical findings about the relation between monetary independence and flexibility of the exchange rate regime. It is much easier to obtain evidence that lend support to the 'irreconcilable duo' hypothesis if one uses the LYS classification rather than our classification. The latter classification is in turn more in line with the Mundellian trilemma.

6. Conclusion

This paper offers a new *de facto* classification of the exchange rate regimes adopted by both advanced economies and emerging and developing economies in the period spanning 1995-2014. We built our classification drawing on the strengths of three popular exchange rate regimes classifications developed by the IMF, Reinhart and Rogoff (2004) and Levy-Yeyati and Sturzenegger (2005). Following the IMF and LYS we went beyond the simple variation of the exchange rate and avoided in this way 'the folly' against which Frankel and Wei (2008) cautioned. Moreover, we allowed for special categories that were (imperfect) analogues of 'inconclusive' and 'freely falling' categories in the LYS and RR classifications, respectively. These minimised the risk of far-fetched precision, although at the expense of classification completeness. Finally, we owe the idea of applying statistical tools – more specifically cluster analysis – to identify actual exchange rate regimes to LYS. Their studies remain – to the best of our knowledge – the only in the literature on exchange rate regimes in which cluster analysis techniques were applied.

It goes without saying that the use of cluster analysis makes our approach substantially different from those employed by the IMF and RR as far as the methodology is concerned. It could be less clear-cut, especially at first sight, that our approach is also different from that of LYS. Thus, it should be emphasised that there are three fundamental differences. First, using the argument based on macroeconomic trilemma, we separated financially open country-years from those that were closed to capital flows, as only the former group could reasonably be used to uncover the empirical standards of fixed and floating exchange rate regimes. The latter group was classified in the subsequent and separate step with the method ensuring classification consistency (the *k*-nearest neighbours method). Second, we applied the robust clustering method when partitioning data points into groups. The trimmed *k*-means method enabled us to tackle the presence of outliers in a formal and impartial way instead of an arbitrary and mechanical elimination of outlying observations. Third, unlike LYS, we did not

isolate the group of intermediate exchange rate regimes, because the characteristics of the relevant cluster seemed to be typical for countries under strong foreign exchange market pressure rather than for either dirty floaters or crawling peggers. In other words, our interpretation of the relevant cluster was more in line with empirical characteristics of country-years included in it. There were also some other, less important differences like the symmetrical treatment of foreign exchange reserves and the exchange rate, the way we standardised data points or the time span covered.

Given all these differences, it is hardly surprising that we found that our classification was different from the one worked out by LYS. It was also different from two other popular classifications developed by the IMF and RR – a simple measure of agreement (the apparent correct classification rate) ranged between 60% and 80% depending on the mapping applied. The formal comparative analysis resulted in three main findings. First, in line with the other studies we found that all classifications were only moderately related: even though the null of independence was strongly rejected for each pair, the strength of association ranged from low to moderate. Second, in a series of pairwise comparisons our classification turned out to be the most strongly associated with each of the other classifications. As such it can be considered – to put it vividly, albeit not very strictly – (closest to) a centre of a space of alternative classifications. Third and most importantly, we demonstrated that there are good grounds for the division of country-years into financially open and closed, which is a characteristic of our classification, as it (i) is based on a sound standard of the peg category, i.e. undistorted by low financial openness; (ii) minimises the impact of differences between market-determined and official exchange rates on the 'fix' and 'float' categories; (iii) is the most appropriate one to assess the importance the exchange rate regime in a debate on the validity of Rey's hypothesis *irrespective* of an a priori judgement on that hypothesis. The most important empirical consequence was that contrary to the LYS classification, ours lent more support to the Mundellian trilemma than to the 'irreconcilable duo' hypothesis.

Overall, these findings imply that the classification we developed cannot be considered a variant of any other *de facto* classification, including the LYS one. It is a genuinely *new* classification.

The two reservations are called for in conclusion. First, our classification requires a refinement that would enable us to identify statistically the intermediate exchange rate regime category. Second, it is well known that the data on changes in foreign exchange reserves only imperfectly proxy for foreign exchange market interventions. We treat these reservations as challenges to our strategy and topics for further research. These also include the use of the

new classification to re-examine such issues as the relations between the exchange rate regime and: external imbalances and international competitiveness (see, e.g., Gervais et al., 2016, Müller-Plantenberg, 2017, Caselli, forthcoming), international trade and global credit supply shocks (see, e.g., Santana-Gallego and Pérez-Rodríguez, 2019, Zeev, 2019), fiscal discipline (see, e.g., Chowdhury et al., 2016) output and inflation volatility (see, e.g., Ghosh, 2014, Hegerty, 2017) as well as political economy variables (see, e.g., Liu et al., forthcoming).

References

Aizenman, J., Chinn, M. D., & Ito, H. (2013). The 'impossible trinity' hypothesis in an era of global imbalances: Measurement and testing. *Review of International Economics*, 21(3), 447–458. https://doi.org/10.1111/roie.12047.

Bernanke, B., & James, H. (1991). The gold standard, deflation, and financial crisis in the Great Depression: An international comparison. In R. G. Hubbard (ed.), *Financial markets and financial crises*. Chicago: University of Chicago Press for NBER, pp. 33–68.

Bleaney, M., & Tian, M. (2017). Measuring exchange rate flexibility by regression methods. *Oxford Economic Papers*, 69(1): 301–319. https://doi.org/10.1093/oep/gpw029.

Bordo, M. D., & James, H. (2017). Capital flows and international order: Trilemmas and trade-offs form macroeconomics to political economy and international relations. In A. R. Ghosh, & M. S. Qureshi (eds.), *From Great Depression to Great Recession: The elusive quest for international policy cooperation*. Washington, D.C.: International Monetary Fund, pp. 91–108.

Bubula A., & Ötker-Robe I. (2002). The evolution of exchange rate regimes since 1990: Evidence from de facto policies. IMF Working Paper WP/02/155.

Calvo, G. A., & Reinhart, C. M. (2002). Fear of floating. *The Quarterly Journal of Economics*, 117(2), 379–408. https://doi.org/10.1162/003355302753650274.

Caselli, F. G. (forthcoming). China's rise, asymmetric trade shocks and exchange rate regimes. *Review of International Economics*. https://doi.org/10.1111/roie.12353.

Chinn, M. D., & Ito, H. (2006). What matters for financial development? Capital controls, institutions, and interactions. *Journal of Development Economics*, 81(1), 163–192. https://doi.org/10.1016/j.jdeveco.2005.05.010.

Chinn, M. D., & Ito, H. (2008). A new measure of financial openness. *Journal of Comparative Policy Analysis*, 10(3), 309–322. https://doi.org/10.1080/13876980802231123.

Chowdhury, M. T. H., Bhattacharya, P. S., Mallick, D., & Ulubaşoğlu, M. A. (2016). Exchange rate regimes and fiscal discipline: The role of trade openness. *International Review of Economics & Finance*, 45, 106-128. https://doi.org/10.1016/j.iref.2016.04.013.

Cuesta-Albertos, J. A., Gordaliza, A., & Matran, C. (1997). Trimmed k-means: An attempt to robustify quantizers. *The Annals of Statistics*, 25(2), 553–576. https://projecteuclid.org/euclid.aos/1031833664.

Dąbrowski, M. A., Śmiech, S., & Papież, M. (2015). Monetary policy options for mitigating the impact of the global financial crisis on emerging market economies. *Journal of*

International Money and Finance, 51: 409–431. https://doi.org/10.1016/j.jimonfin.2014.12.006.

Disyatat, P., & Rungcharoenkitkul, P. (2016). Financial globalisation and monetary independence. BIS Papers No 88: 213–225.

ECB (2010). *Convergence report: May 2010*, Frankfurt am Main: European Central Bank.

Edwards, S. (2015). Monetary Policy Independence under Flexible Exchange Rates: An Illusion?. *The World Economy*, 38(5), 773–787. https://doi.org/10.1111/twec.12262.

Eichengreen, B., & Razo-Garcia, R. (2013). How reliable are de facto exchange rate regime classifications? *International Journal of Finance & Economics*, 18 (3): 216–239. https://doi.org/10.1002/ijfe.1456.

Fix, E., & Hodges Jr., J. L. (1951). *Discriminatory analysis-nonparametric discrimination: consistency properties*. Berkeley: California University.

Frankel, J., & Wei, S.-J. (1994). Yen bloc or dollar bloc? Exchange rate policies of the east Asian economies. In I. Takatoshi & A. O. Krueger (ed.), *Macroeconomic linkage: Savings, exchange rates, and capital flows*. Chicago: University of Chicago Press, pp. 295–329.

Frankel, J., & Wei, S.-J. (2008). Estimation of de facto exchange rate regimes: Synthesis of the techniques for inferring flexibility and basket weights. *IMF Staff Papers*, 55(3), 384–416.

Frankel, J., & Xie, D. (2010). Estimation of de facto flexibility parameter and basket weights in evolving exchange rate regimes. *American Economic Review: Papers and Proceedings*, 100(2), 568–572. https://doi.org/10.1257/aer.100.2.568.

Gallegos, M. T. (2002). Maximum likelihood clustering with outliers. In K. Jajuga, A. Sokolowski, and H. H. Bock (eds.), *Classification, clustering and data analysis: recent advances and applications*. Berlin: Springer-Verlag, pp. 247–255.

García-Escudero L. Á., & Gordaliza, A (1999). Robustness properties of *k* means and trimmed *k* means. *Journal of American Statistical Association*, 94(447): 956–969. https://doi.org/10.1080/01621459.1999.10474200.

García-Escudero, L. Á., Gordaliza, A., Matrán, C., & Mayo-Iscar, A. (2010). A review of robust clustering methods. *Advances in Data Analysis and Classification*, 4(2-3), 89–109. https://doi.org/10.1007/s11634-010-0064-5.

García-Escudero, L. A., Gordaliza, A., Matrán, C., & Mayo-Iscar, A. (2011). Exploring the number of groups in robust model-based clustering. *Statistics and Computing*, 21(4), 585–599. https://doi.org/10.1007/s11222-010-9194-z.

Gervais, O., Schembri, L., & Suchanek, L. (2016). Current account dynamics, real exchange rate adjustment, and the exchange rate regime in emerging-market economies. *Journal of Development Economics*, 119: 86-99. https://doi.org/10.1016/j.jdeveco.2015.10.003.

Ghosh, A. (2014). How do openness and exchange-rate regimes affect inflation?. *International Review of Economics & Finance*, 34, 190-202. https://doi.org/10.1016/j.iref.2014.08.008.

Ghosh, A. R., Gulde, A.-M., & Wolf, H. C. (2002). *Exchange rate regimes: Choices and consequences*. Cambridge, MA & London: The MIT Press.

Habermeier, K, Kokenyne, A., Veyrune, R., & Anderson, H. (2009). Revised system for the classification of exchange rate arrangements. IMF Working Paper WP/09/211.

Harms, P., & Kretschmann, M. (2009). Words, deeds and outcomes: A survey on the growth effects of exchange rate regimes. *Journal of Economic Surveys*, 23 (1): 139–164. https://doi.org/10.1111/j.1467-6419.2008.00559.x.

Hegerty, S. W. (2017). Inflation Volatility, Monetary Policy, and Exchange-Rate Regimes in Central and Eastern Europe: Evidence from Parametric and Nonparametric Analyses. *Eastern European Economics*, 55 (1), 70–90. https://doi.org/10.1080/00128775.2016.1253022.

Ilzetzki, E., Reinhart, C. M., & Rogoff, K. S. (2011). The country chronologies and background material to exchange rate arrangements into the 21st century: Will the anchor currency hold. Available at personal.lse.ac.uk/ilzetzki/data/ERA-Country_Chronologies_2011.pdf (accessed on January 2, 2019).

Ilzetzki, E., Reinhart, C. M., & Rogoff, K. S. (2017). Exchange arrangements entering the 21st century: which anchor will hold?. NBER Working Paper No. 23134.

IMF (2007). *Annual Report on Exchange Arrangements and Exchange Restrictions 2007*. Washington, D.C.: International Monetary Fund.

IMF (n.a.). *International Financial Statistics*. On-line database, http://data.imf.org/ (accessed on July 16, 2016).

Kaufman, L., & Rousseeuw, P. J. (1990). Finding groups in data: an introduction to cluster analysis. New York: Wiley.

Kotsiantis, S. B. (2007). Supervised machine learning: A review of classification techniques. *Informatica*, 31: 249–268.

Klein, M. W., & Shambaugh, J. C. (2010). *Exchange rate regimes in the modern era*. Cambridge, MA and London: MIT Press.

Levy-Yeyati, E., & Sturzenegger, F. (2005). Classifying exchange rate regimes: Deeds vs. words. *European Economic Review*, 6(49), 1603–1635. https://doi.org/10.1016/j.euroecorev.2004.01.001.

Levy-Yeyati, E., & Sturzenegger, F. (2016). Classifying Exchange rate regimes: 15 years later. CID Faculty Working Paper No. 319.

Liu, J., Wei, W., Shi, Y.-B., & Chang, C.-P. (forthcoming). The nexus between country risk and exchange rate regimes: A global investigation. *North American Journal of Economics and Finance*. https://doi.org/10.1016/j.najef.2018.08.025

Mohamad, I. B., & Usman, D. (2013). Standardization and its effects on k-means clustering algorithm. *Research Journal of Applied Sciences, Engineering and Technology*, 6(17): 3299–3303.

Müller-Plantenberg, N. A. (2017). Boom-and-bust Cycles, External Imbalances and the Real Exchange Rate. *The World Economy*, 40 (1), 56-87. https://doi.org/10.1111/twec.12322.

Obstfeld, M., & Rogoff, K. S. (1995). The mirage of fixed exchange rates. *Journal of Economic Perspectives*, 9 (4), 73–96. https://doi.org/10.1257/jep.9.4.73.

Obstfeld, M., & Rogoff, K. S. (2000). The six major puzzles in international macroeconomics: Is there a common cause?. *NBER Macroeconomics Annual 2000*, 115(1), 339–90.

Reinhart, C. M., & Rogoff, K. S. (2004). The modern history of exchange rate arrangements: A reinterpretation. *The Quarterly Journal of Economics*, 119(1), 1–48. https://doi.org/10.1162/003355304772839515.

Rey, H. (2015/2018). Dilemma not trilemma: The global financial cycle and monetary policy independence. NBER Working Paper No. 21162.

Rey, H. (2016), International channels of transmission of monetary policy and the Mundellian trilemma, *IMF Economic Review*, 64 (1): 6–35.

Rencher, A. C. (2003). *Methods of multivariate analysis* (Vol. 492). John Wiley & Sons.

Rose, A. K. (2011). Exchange rate regimes in the modern era: fixed, floating, and flaky. *Journal of Economic Literature*, 49(3), 652–672. https://doi.org/10.1257/jel.49.3.652.

Rousseeuw, P. J. (1987). Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. *Journal of Computational and Applied Mathematics*, 20, 53–65. https://doi.org/10.1016/0377-0427(87)90125-7

Sachs, J. D. (1996). Economic transition and the exchange-rate regime. *American Economic Review: Papers and Proceedings*, 86(2), 147–152. https://www.jstor.org/stable/2118113.

Santana-Gallego, M., & Pérez-Rodríguez, J. V. (2019). International trade, exchange rate regimes, and financial crises. *North American Journal of Economics and Finance*, 47, 85-95. https://doi.org/10.1016/j.najef.2018.11.009.

Shambaugh, J. C. (2004). The effect of fixed exchange rates on monetary policy. *The Quarterly Journal of Economics*, 119(1), 301–352. https://doi.org/10.1162/003355304772839605.

Stevenson, A. (2002a). Fixed exchange rate system. In B. Snowdon and H. R. Vane, eds. *An encyclopedia of macroeconomics*. Cheltenham, UK and Northampton, MA: Edward Elgar, pp. 249–259.

Stevenson, A. (2002b). Flexible exchange rate system. In B. Snowdon and H. R. Vane, eds. *An encyclopedia of macroeconomics*. Cheltenham, UK and Northampton, MA: Edward Elgar, pp. 259–266.

Tavlas, G., Dellas, H., & Stockman, A. (2008). The classification and performance of alternate exchange-rate systems. *European Economic Review*, 52, 941–963. https://doi.org/10.1016/j.euroecorev.2008.02.003.

Zeev, N. B. (2019). Global credit supply shocks and exchange rate regimes. *Journal of International Economics*, 116, 1-32. https://doi.org/10.1016/j.jinteco.2018.10.002.

Appendix

to 'Classifying *de facto* exchange rate regimes of financially open and closed economies: A statistical approach'

(for on-line publication)

Table A1. Anchor currencies, 1995-2015

Anchor currency	Number of countries*	Countries
Australian dollar (AUD)	1 (0.6%)	Kiribati
Euro (EUR)	53 (29.8%)	Albania, Austria, Belgium, Benin, Bosnia and Herzegovina, Bulgaria, Burkina Faso, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Republic of Congo, Cote d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Equatorial Guinea, Estonia, Finland, France, Gabon, Germany, Greece, Guinea-Bissau, Hungary, Iceland, Ireland, Italy, Luxembourg, FYR Macedonia, Madagascar, Mali, Malta, Montenegro, Morocco, Netherlands, Niger, Norway, Poland, Portugal, Romania, San Marino, Senegal, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Togo, Tunisia, Turkey, United Kingdom, United States of America
Indian rupee (INR)	1 (0.6%)	Bhutan
South African Rand (ZAR)	4 (2.2%)	Botswana, Lesotho, Namibia, Swaziland
U.S. dollar (USD)	113 (63.5%)	Afghanistan, Angola, Anguilla, Antigua and Barbuda, Argentina, Armenia, Aruba, Australia, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belize, Bolivia, Brazil, Brunei Darussalam, Burundi, Cambodia, Canada, Chile, China, Colombia, Democratic Republic of Congo, Costa Rica, Curacao & St. Maarten, Djibouti, Dominica, Dominican Republic, Egypt, El Salvador, Eritrea, Ethiopia, Fiji, Gambia, Georgia, Ghana, Grenada, Guatemala, Guinea, Guyana, Haiti, Honduras, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Jamaica, Japan, Jordan, Kazakhstan, Kenya, South Korea, Kuwait, Kyrgyzstan, Laos, Lebanon, Liberia, Macao, Malawi, Malaysia, Maldives, Mauritania, Mauritius, Mexico, Federated States of Micronesia, Moldova, Mongolia, Montserrat, Mozambique, Nepal, New Zealand, Nicaragua, Nigeria, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Qatar, Russia, Rwanda, Samoa, Saudi Arabia, Seychelles, Sierra Leone, Singapore, Solomon Islands, South Africa, Sri Lanka, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Sudan, Suriname, Tajikistan, Tanzania, Thailand, Tonga, Trinidad and Tobago, Uganda, Ukraine, United Arab Emirates, Uruguay, Vanuatu, Venezuela, Vietnam, Yemen, Zambia
Special drawing rights (SDR)	2 (1.1%)	Libya, Myanmar
Change	4 (2.2%)	From EUR to USD: Algeria (2003) From USD to EUR: Lithuania (2002), Sao Tome and Principe (2008) From SDR to EUR: Latvia (2005)

Notes: * percentage of total in parentheses. Anchor currencies are available in an xlsx format.

Table A2. *De facto* exchange rate regime classification, 1995-2014

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Afghanistan																				
Albania	Float	Float	Outlier	Float	Float	Float	Float	Float	Float	Float	Float	Incon	Float	Incon	Float	Fix	Incon	Incon	Incon	Incon
Algeria	Float	Fix	Float	Float	Fix	Float	Float	Float	Float	Incon	Float	Float	Float	Float	Incon	Incon	Float	Float	Float	Float
Angola		Outlier	U_press	U_press	Outlier	Outlier	Float	Fix	Float	Float	Float	Fix	Float	Fix	Float	Fix	Float	Fix	Fix	Float
Anguilla																				
Antigua and Barbuda	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix					
Argentina	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Float	Float	Fix	Fix	Fix	Float	Float	Incon	Incon	Float	Float	Float
Armenia		Fix	Fix	Fix	Float	Float	Incon	Float	Fix	Float	Float	Float	Float	Incon	Float	Float	Float	Float	Float	Float
Aruba	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Australia	Float	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Outlier	Fix	Float	Float	Float
Austria	Fix	Float	Incon	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Azerbaijan		Fix	Fix	Incon	Float	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Bahamas	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Bahrain	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Bangladesh	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Barbados	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Belarus		Float	Float	U_press	Outlier	Outlier	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	U_press	U_press	Outlier	Float	Fix	Fix
Belgium	Fix	Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Belize	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Benin	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Bhutan	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Bolivia	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Incon	Incon	Fix	Fix	Fix
Bosnia and Herzegovina					Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Botswana	Fix	Incon	Incon	Incon	Incon	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Brazil	Float	Incon	Fix	Fix	Outlier	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Brunei Darussalam																				
Bulgaria	Float	Outlier	Outlier	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Burkina Faso	Fix	Float	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Burundi	Float	Float	Float	Float	Float	Float	Float	Float	Fix	U_press	Float	U_press	U_press	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Cabo Verde	Fix	Outlier	U_press	U_press	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Cambodia	Float	Float	Float	Float	Incon	Incon	Incon	Fix	Fix	Incon	Incon	Float	Fix	Fix	Incon	Incon	Incon	Float	Fix	Fix
Cameroon	Outlier	Outlier	U_press	Outlier	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Canada	Float	Float	Fix	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Central African Rep.	Fix	Float	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Chad	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Chile	Float	Incon	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
China	Fix	Incon	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Incon	Incon	Incon	Incon	Incon	Incon	Incon	Incon	Incon	Incon
Colombia	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Comoros		Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix

Table A2. *De facto* exchange rate regime classification, 1995-2014, cont'd

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Congo, Democratic Rep. of	Outlier	Outlier						Fix	U_press	U_press	Outlier	U_press	U_press	U_press	Outlier	Fix	Fix	Fix		
Congo, Rep. of	Fix	U_press	Outlier	U_press		Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Costa Rica	Float	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Float	Float	Float	Incon	Fix	Fix	Float
Cote d'Ivoire	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Croatia		Float	Incon	Incon	Fix	Fix	Float	Fix	Fix	Float	Float	Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Curacao																				
Cyprus	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Czech Rep.		Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Incon
Denmark	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Incon	Incon	Fix
Djibouti	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Dominica	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Dominican Rep.	Float	Float	Fix	Fix	Fix	Fix	Fix	Float	Outlier	Outlier	Float	Float	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Egypt	Fix	Incon	Fix	Fix	Incon	Float	Float	Fix	Float	Incon	Float	Incon	Incon	Incon	Incon	Incon	Fix	Fix	Fix	Fix
El Salvador	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Equatorial Guinea	Fix	Outlier		Outlier	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Eritrea				U_press	U_press	Outlier	Outlier	Fix	Fix	Fix	Float	Fix	Fix	Fix	Fix	Fix	Fix			
Estonia		Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Ethiopia	Float	Fix	Float	Float	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix					
Euro area																				
Fiji	Float	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Fix	Float	Float	Float	Float	Fix	Float	Float	Float
Finland	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
France	Fix	Incon	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Gabon	Fix	U_press	U_press	U_press	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Gambia	Fix	Incon	Fix	Incon	Float	Float	Float	Float	Float	Fix	Float	Fix	Outlier	Float	Fix	Float	Float	Float	Outlier	Float
Georgia		Fix	Fix	U_press	Outlier	Float	Float	Fix	Float	Float	Fix	Fix	Fix	Fix	Fix	Float	Float	Incon	Float	Float
Germany	Fix	Incon	Incon	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Ghana	Float	Fix	Fix	Fix	Float	Outlier	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Float	
Greece	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Grenada	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Guatemala	Float	Float	Float	Fix	Float	Float	Fix	Float	Fix	Fix	Incon	Incon	Incon	Incon	Incon	Fix	Float	Float	Fix	Incon
Guinea	Fix	U_press	U_press	U_press	Float	Float	Fix	Fix		Float	Float							Outlier	Outlier	Outlier
Guinea-Bissau	Float	U_press	U_press	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Guyana	Fix	Incon	Incon	Float	Float	Incon	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Haiti	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Incon	Fix	Float	Incon	Fix	Fix	Fix
Honduras	Float	Fix	Fix	Fix	Float	Incon	Fix	Fix	Fix	Fix	Incon	Fix	Fix	Incon	Fix	Fix	Fix	Fix	Fix	
Hong Kong SAR, China			Fix	Incon	Incon	Incon	Fix	Fix	Fix	Incon	Incon	Incon	Incon	Incon	Fix	Incon	Incon	Incon	Incon	Incon
Hungary	Float	Float	Float	Float	Float	Fix	Float	Float	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Iceland	Fix	Fix	Fix	Fix	Fix	Float	Float	Fix	Float	Float	Float	Outlier	Float	Float	Float	U_press	Fix	Float	Float	Float
India	Float	Float	Float	Float	Incon	Float	Incon	Fix	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Indonesia	Fix	Incon	Outlier	Float	Outlier	Outlier	Outlier	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float

Table A2. *De facto* exchange rate regime classification, 1995-2014, cont'd

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Iran, Islamic Rep. of																				
Iraq																				
Ireland	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Israel	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Italy	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Jamaica	Float	Float	Incon	Incon	Float	Fix	Fix	Fix	Float	Fix	Float	Fix	Float	Fix	Float	Fix	Fix	Fix	Fix	Fix
Japan	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Jordan	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Kazakhstan		Fix	Fix	Fix	Outlier	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix	Float	Fix	Fix	Fix	Fix	Float
Kenya	Float	Fix	Float	Float	Float	Float	Incon	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Fix	Float	Fix
Kiribati																				
Korea, Rep. of	Float	Float	Outlier	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Kuwait	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Kyrgyz Rep.			Fix	Fix	Float	Float	Float	Fix	Float	Fix	Incon	Float	Float	Float	U_press	Incon	Float	Incon	Fix	Float
Lao People's Democratic Rep.	Float	Fix	Float	Float	Outlier	Float	Float	Float	Fix	Float	Float	Float	Fix	Fix	Incon	U_press	Fix	U_press	U_press	U_press
Latvia		Incon	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Incon	Fix	Fix	Fix	Float	Fix	Incon	Fix
Lebanon	Fix	Incon	Incon	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Lesotho	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Liberia	Fix	Fix	Fix	Outlier	Float	Float	Outlier	Outlier	Outlier	Outlier	Float	Float	Float	Fix	Float	Float	Float	Fix	Fix	Fix
Libya					Fix	Float	Float	Float	Float	Fix	Fix	Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Lithuania		Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Luxembourg					Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Macao SAR, China																				
Macedonia, FYR			Float	Fix	Fix	Fix	Fix	Float	Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Madagascar	Float	Float	Fix	Float	Float	Float	Float	Float	Float	Outlier	Float	Float	Float	Float	Float	Float	Float	Float	Float	Fix
Malawi	Fix	U_press	U_press	Float	Fix	Outlier	Float	Fix	Float	Fix	U_press	U_press	Outlier	Outlier	U_press	Outlier	U_press	Outlier	Outlier	Outlier
Malaysia	Float	Incon	Float	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float
Maldives	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix	Fix
Mali	Fix	Fix	Fix	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Malta	Float	Incon	Fix	Incon	Float	Float	Float	Fix	Fix	Incon	Fix	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Mauritania	Float	Fix	Fix								Outlier	Fix	U_press	Outlier	U_press	Outlier	U_press	U_press		
Mauritius	Float	Float	Float	Float	Fix	Fix	Fix	Fix	Float	Float	Incon	Float	Float	Float	Float	Float	Float	Float	Float	Fix
Mexico	Outlier	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Micronesia, Fed. Sts.		Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Moldova		Fix	Fix	Float	Float	Float	Float	Float	Float	Float	Fix	Float	Float	Float	Fix	Float	Float	Float	Float	Float
Mongolia	Float	Float	Float	Fix	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Float	Float	Float	Float
Montenegro																				
Montserrat																				
Morocco	Fix	Float	Incon	Incon	Float	Float	Fix	Fix	Fix	Incon	Fix	Incon	Incon	Fix	Float	Fix	Fix	Fix	Fix	Fix
Mozambique	Float	Fix	Fix	Float	Float	Float	Float	Fix	Fix	Float	Outlier	Float	Float	Fix	Float	Float	Float	Float	Fix	Float

Table A2. *De facto* exchange rate regime classification, 1995-2014, cont'd

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Myanmar	Fix	U_press	U_press	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Incon	Fix	Fix	Incon	Outlier		
Namibia	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Nepal	Float	Float	Float	Float	Incon	Float	Fix	Fix	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Netherlands	Fix	Incon	Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
New Zealand	Float	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Nicaragua	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Incon	Incon	Incon	Fix	Fix	Fix	Incon	Fix
Niger	Fix	Fix	Fix	Outlier	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Nigeria	Fix	Fix	Fix	Fix	Outlier	Float	Float	Float	Float	Fix	Fix	Fix	Float	Float	Float	Incon	Float	Fix	Fix	Float
Norway	Fix	Fix	Fix	Float	Float	Fix	Fix	Float	Float	Float	Float	Float	Float	Fix	Float	Fix	Fix	Fix	Float	Float
Oman	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Pakistan	Float	U_press	U_press	Outlier	Fix	Float	U_press	Fix	Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Float	Float	U_press	U_press
Panama	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Papua New Guinea	Fix	U_press	Float	U_press	Outlier	Outlier	Float	Float	Float	Fix	Fix	Fix	Float	Fix	Float	Float	Float	Float	Float	Fix
Paraguay	Fix	Fix	Fix	Float	U_press	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Peru	Float	Float	Incon	Incon	Float	Incon	Float	Float	Fix	Float	Float	Float	Float	Float	Float	Fix	Incon	Float	Float	Float
Philippines	Float	Fix	Float	Float	Float	Float	Float	Float	Float	Incon	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Poland	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Incon
Portugal	Float	Float	Incon	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Qatar	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Romania	Float	Fix	Outlier	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Fix	Float	Float	Float	Float
Russian Federation		Fix	Fix	U_press	Float	Fix	Fix	Fix	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Outlier	Float	Outlier
Rwanda	Outlier	Fix	Float	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Samoa	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Fix	Float	Fix	Float
San Marino																				
Sao Tome and Principe		Float	Outlier	Fix	Fix	Float	Fix	Fix	Fix	Fix	U_press	U_press	Fix	Fix	Float	Fix	Fix	Fix	Fix	Fix
Saudi Arabia	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Outlier	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Senegal	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Serbia																				
Seychelles	Float	Fix	U_press	U_press	U_press	U_press	Float	Fix	Float	Fix	Fix	Fix	Outlier	Outlier	Outlier	Fix	Float	Float	Float	Float
Sierra Leone	Float	Float	Float	Float	Float	Outlier	U_press	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix	Fix	Fix	Float
Singapore	Float	Incon	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Slovak Rep.		Incon	Float	Float	Fix	Float	Float	Fix	Fix	Fix	Float	Float	Float	Float	Fix	Fix	Fix	Fix	Fix	Fix
Slovenia		Fix	Incon	Fix	Incon	Fix	Fix	Fix	Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Solomon Islands	Fix	Fix	Float	Float	Float	Fix	Fix	Float	Fix	Fix	Fix	Incon	Fix	Fix	Fix	Fix	Fix	Fix	Incon	Float
South Africa	Fix	U_press	U_press	Float	Float	Float	Float	Float	Float	Float	Float	Outlier	Float	Float	Float	Float	Float	Float	Float	Float
Spain	Float	Float	Incon	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Sri Lanka	Float	Incon	Fix	Float	Incon	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix
St. Kitts and Nevis	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
St. Lucia	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
St. Vincent and the Grenadines	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix

Table A2. *De facto* exchange rate regime classification, 1995-2014, cont'd

Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Sudan	Float	Float	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix		U_press	Outlier				
Suriname	Float	Fix	Fix	Fix	Outlier	Outlier	Outlier	Float	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix	Fix
Swaziland	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Sweden	Float	Fix	Fix	Fix	Float	Float	Fix	Float	Fix	Float	Float	Float	Float	Fix	Fix	Float	Float	Float	Fix	Float
Switzerland		Float	Float	Float	Incon	Float	Float	Fix	Fix	Float	Fix	Incon	Float	Float	Fix	Float	Float	Fix	Float	Incon
Tajikistan			Outlier	U_press	U_press	Outlier	Fix	Float	Fix	Fix	Incon	Float	Outlier	Fix	Outlier	Outlier	Outlier	Outlier	Fix	Outlier
Tanzania, United Rep. of	Float	Float	Float	Float	Float	Fix	Float	Float	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Fix	Float	Float
Thailand	Fix	Incon	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Incon	Float	Float	Float	Float	Float
Togo	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
Tonga	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix	Fix	Fix	Float	Float	Fix	Fix	Float	Float	Fix	Float	Float	Float
Trinidad and Tobago	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Incon	Incon	Incon	Incon	Incon	Fix
Tunisia	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Float	Float	Float	Float	Incon	Float	Fix	Fix	Float	Float
Turkey	Float	Float	Float	Float	Float	Float	Outlier	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Uganda	Float	Float	Float	Float	Float	Float	Float	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Ukraine		U_press	Fix	U_press	Float	U_press	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Float	Fix	Fix	Fix	Fix	Fix	Outlier
United Arab Emirates	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix	Fix
United Kingdom	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
United States	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Uruguay	Float	Float	Float	Fix	Float	Fix	Float	Float	Float	Fix	Float	Float	Float	Float	Float	Float	Float	Float	Float	Float
Vanuatu	Float	Incon	Float	Float	Float	Float														
Venezuela	Float	Outlier	Fix	Fix	Float	Fix	Fix	Float	Float	Float	Float	Fix	Fix	Fix	Fix	Outlier	Outlier	Fix	Outlier	Fix
Vietnam	Fix	Fix	Float	Incon			Float	Fix	Fix	Incon	Fix	Fix	Fix	Fix	Float	Fix	Fix	Fix	Fix	Fix
Yemen	Outlier	Outlier	Incon	Fix	Float	Float		Fix	Fix	Incon	Float	Incon	Incon	Incon	Incon	Float	Fix	Fix	Fix	
Zambia	U_press	U_press	Fix	Fix	U_press		Outlier	U_press	Float	Float	Outlier	Outlier	Float	Float	Float	Float	Fix	U_press	Float	Outlier

Notes: 'Incon' stands for inconclusive, 'U_press' – for under pressure. The classification is available in an xlsx format.

Table A3. Association measures: new classification vs. alternatives under mapping into pegs and non-pegs

Classifications considered	Period considered	Pearson chi-square [a)]	Cramér's V [b)]	*Lambda* [b)]	Apparent correct classification rate
Our Class. vs LYS	1995-2013	647.8***	0.470	0.309	0.713
Our Class. vs RR	1995-2014	1,200.1***	0.605	0.519	0.789
Our Class. vs IMF	1995-2010	311.1***	0.366	0.229	0.669
LYS vs RR	1995-2013	1,000.1***	0.566	0.516	0.342
LYS vs IMF	1995-2010	357.1***	0.391	0.274	0.302
RR vs IMF	1995-2010	538.4***	0.465	0.374	0.740

Notes: see Table 10 in the main text.

Table A4. Association measures: new classification vs. alternatives under mapping into floats and non-floats

Classifications considered	Period considered	Pearson chi-square [a)]	Cramér's V [b)]	*Lambda* [b)]	Apparent correct classification rate
Our Class. vs LYS	1995-2013	685.5***	0.484	0.308	0.769
Our Class. vs RR	1995-2014	108.6***	0.182	0.050	0.697
Our Class. vs IMF	1995-2010	200.6***	0.294	0.077	0.707
LYS vs RR	1995-2013	71.4***	0.151	0.039	0.672
LYS vs IMF	1995-2010	99.3***	0.206	0.025	0.666
RR vs IMF	1995-2010	118.2***	0.218	0.056	0.802

Notes: see Table 10 in the main text.

Table A5. Descriptive statistics of monetary independence index under alternative exchange rate regime classifications

	Financially open economies				Financially closed and open economies			
	Floating exchange rate regime		Fixed exchange rate regime		Floating exchange rate regime		Fixed exchange rate regime	
Statistic	DPS	LYS	DPS	LYS	DPS	LYS	DPS	LYS
Mean	0.4699	0.3666	0.3174	0.3979	0.4833	0.4073	0.3833	0.4298
Median	0.4599	0.3900	0.3521	0.3987	0.4862	0.4397	0.4158	0.4506
Maximum	1.0000	1.0000	0.9401	1.0000	1.0000	1.0000	0.9679	1.0000
Minimum	0.0106	0.0000	0.0000	0.0166	0.0106	0.0000	0.0000	0.0113
Std. deviation	0.2066	0.2680	0.2362	0.1993	0.1958	0.2532	0.2225	0.1912
Skewness	0.3034	0.1505	0.0497	0.0089	0.1337	-0.1257	-0.3008	-0.2139
Kurtosis	2.9767	2.2282	1.8869	2.4653	2.9937	2.3311	2.2307	2.7009
WW-M test (p value in parentheses)	7.1464 (0.0000)		6.3612 (0.0000)		5.9511 (0.0000)		4.8215 (0.0000)	

Notes: DPS stands for our classification, LYS – for Levy-Yeyati and Sturzenegger's classification; WW-M test stands for Wilcoxon/Mann-Whitney (tie-adjusted) test; the null is that medians are equal.

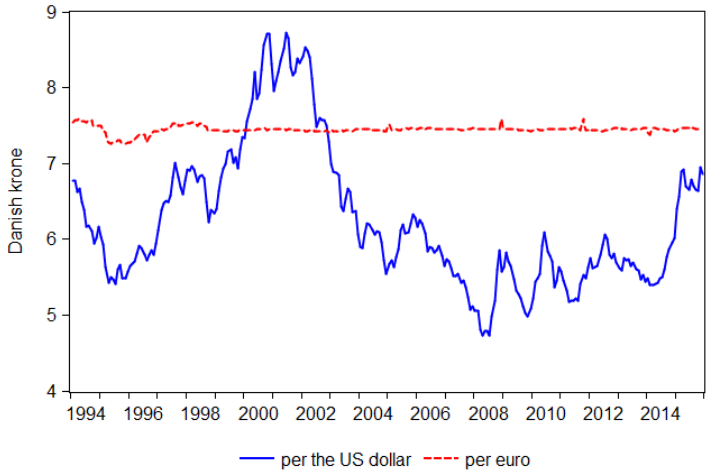


Figure A1. Exchange rates of the Danish krone

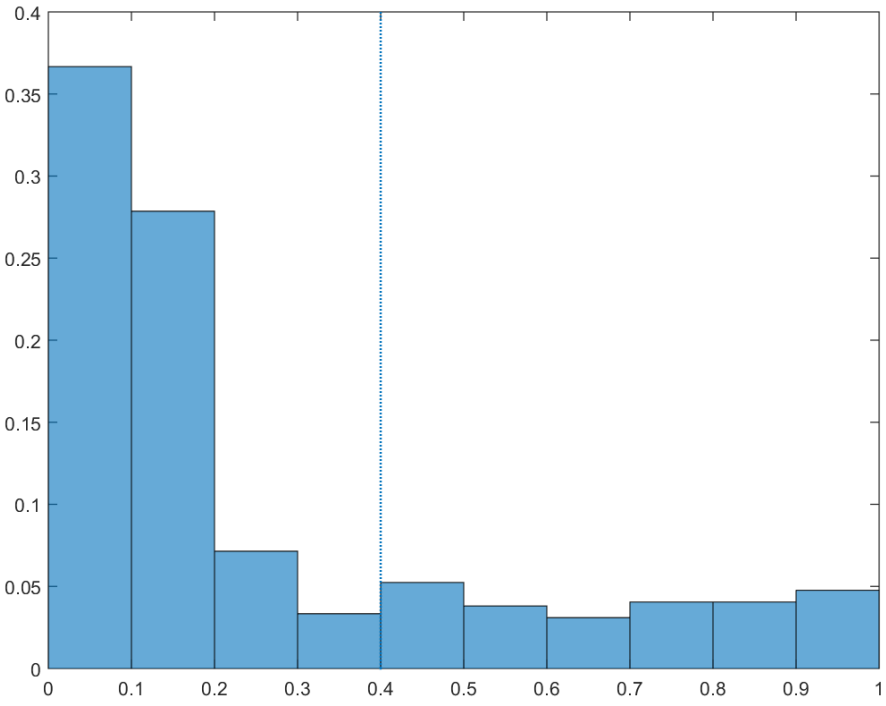


Figure A2. Distribution of the Chinn-Ito index for country-years with non-unitary exchange rates

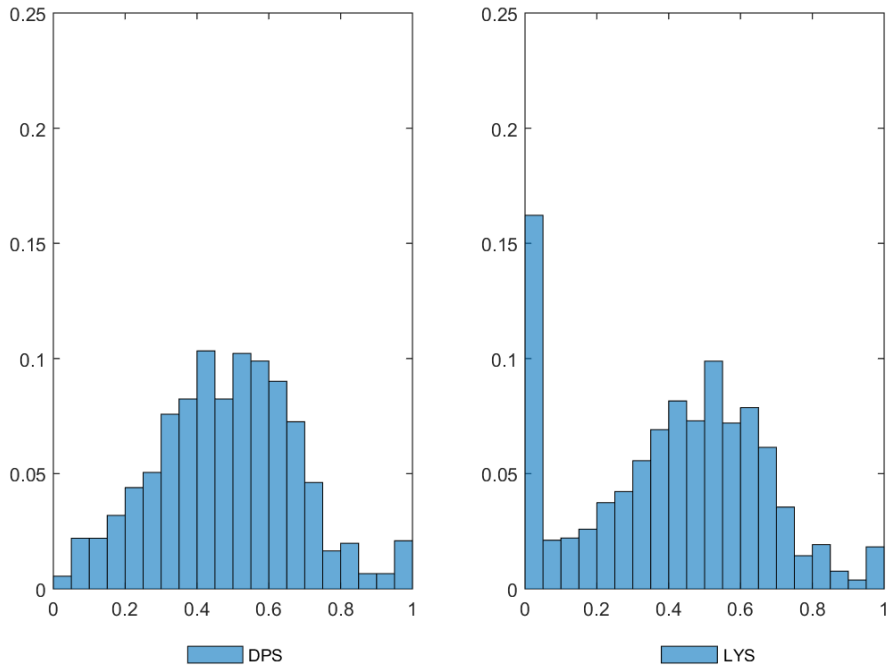


Figure A3. Distribution of monetary independence index under the floating exchange rate regime in financially closed and open economies

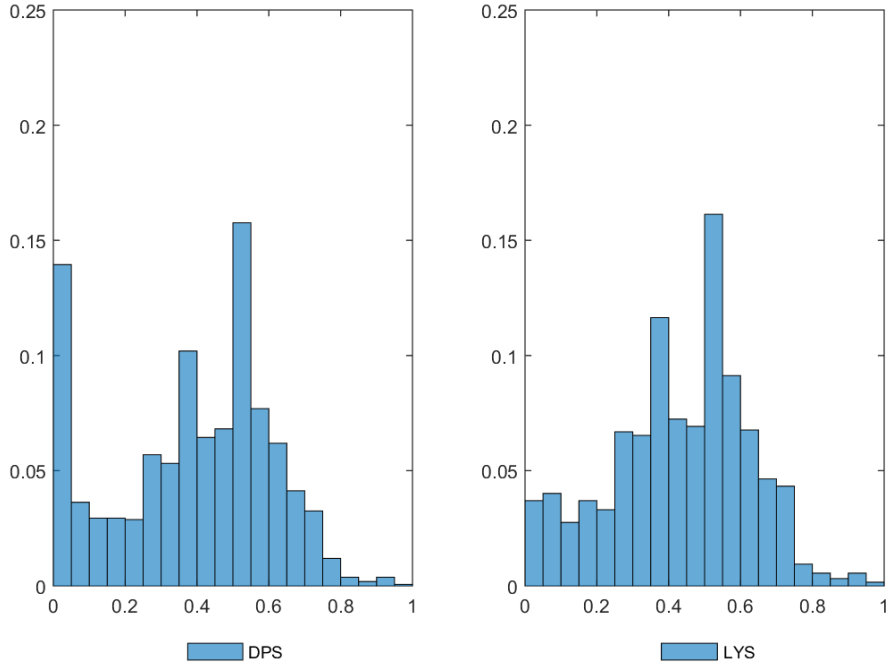


Figure A4. Distribution of monetary independence index under the fixed exchange rate regime in financially closed and open economies