Gold and Trade: An empirical simulation approach

Rui Esteves[a], Florian Ploeckl[b]

[a] *University of Oxford, Department of Economics, Oxford, OX1 3UQ, UK*
[b] *University of Adelaide, School of Economics, Adelaide, SA 5005, Australia*

Abstract

The network externalities from international trade to the choice of exchange rate regimes have been invoked to explain the rise of the classical gold standard. In particular, gravity regressions have consistently shown large trade gains for countries on the same monetary regime (especially gold). However, causality probably runs in both directions, since more open economies would have a greater incentive to adopt stable exchange rate regimes, especially if they traded more with other countries already on gold. This raises an endogeneity issue for which conventional identification methods are not suitable. This paper uses empirical network analysis to model the co-evolution of trade and exchange rate regimes. Preliminary results suggest that the network externalities from trade were indeed strong and conditioned the choice of monetary regimes. The monetary regime of trade partners also influenced the configuration of each country's trade network. However, common monetary standards *per se* did not increase the likelihood that two countries traded, contrary to the existing estimates in the literature.

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1. Introduction

The global economy from the second half of the 19th century until World War I experienced two major trends in international trade and finance. The First Globalization led the fast growth of world trade, characterised by an expansion of the range of goods traded as well as the countries involved in the global system. Simultaneously, a gold peg became the monetary orthodoxy of the period, as many nations decided to adopt the gold standard. The link between these two developments has long been remarked and contemporaries were keenly aware of the advantages of adopting the monetary regime of their main trade partners. Because shared monetary regimes and enhanced trade relations are mutually reinforcing they create 'network externalities' which have been the object of intensive study in the literature on the late 19th century and our own wave of Globalization (Estevadeordal et al., 2003; Rose, 2000; Rose & Glick, 2016).

Several studies[1] have shown how network effects swayed countries' decisions to adopt gold. However, the identification of causal relations in networks with traditional statistical methods is very hard, in the absence of natural experiments. This project introduces a new estimation method that allows to account for possible endogeneity in these settings.

We investigate the relationship between trade and monetary arrangements and address the endogeneity issue by employing a RSiena simulation approach (Steglich et al., 2010). This method, recently developed in the sociology literature to address questions of influence and selection, utilizes a Stochastic Actor Oriented Model to simulate the development of network structures and behavioural characteristics (Snijders et al., 2010). The method requires a basic network setup, which in our case is based on trade relationships, and explains the changes in actor behaviour as optimal reactions to the contemporary network structure and the behaviour of other actors. In this paper we retain as behavioural variable the choice of monetary system and, in particular, the decision to adopt a gold peg.

We apply this method to the late 19th century in order to investigate the the role of trade in the development of the international monetary system as well as the impact of the international convergence onto the gold standard on the trade system of the First Globalization. We focus on a set of 42 independent countries with the ability to set their own monetary and trade arrangements. The time range covers little over six decades, from the 1850s until the disruptions of World War I.

The next section introduces the historical setting of trade and monetary

[1] In particular gravity studies like Meissner (2005)

arrangements between 1850 and 1913, as well as the literature on the subject. Section 3 then describes the details of the method, and its application to the historical case occupies section 4. The preliminary results are presented and discussed in section 5 and the paper ends with some intermediate conclusions and directions for future research.

2. Historical Setting

The literature on the rise of the classical gold standard during the 19th century can still be usefully summarised in the three categories identified by Gallarotti (1995), namely, structural, proximate and permissive forces. Structural forces encompassed long-term trends that favoured the adoption of gold, while proximate sources acted as catalysts in particular periods. Finally, permissive forces determined whether individual countries could act on the previous two by joining (or remaining on) gold. Among the structural forces one can include the trends toward industrialisation and economic growth, or the ideology of gold, which persisted into the interwar (Eichengreen & Temin, 2010; Yeager, 1984). These explanations are the prime ground for political economy models of monetary regimes, which explore the distributional consequences of the adoption of a stable exchange rate regime. In these accounts, the gold standard had to be imposed by a combination of stable money interests (importers, banking/finance, industrial) against coalitions of indebted farmers, landowners, silver miners and exporters (Broz, 1997; Mitchener & Voth, 2011). These conflicts were played inside each country, but also in the international arena of a series of monetary conferences convened in the second half of the 19th century to solve the 'monetary question' (Reti, 1998).

In spite of these underlying structural forces and the efforts of international conferences to standardise the monetary regime, countries mostly joined gold in their own time (or not at all).[2] Moreover, the pattern of monetary regimes reproduced in Figure 1 reveals a number of clustered conversions to gold. The most famous is the so-called 'scramble for gold' of the early 1870s, when a number of European nations rushed to join once France and Germany had done so. Over the remaining decades a number of emerging nations also adopted gold, which became the predominant monetary regime by the early 20th century.

[2]In the absence of a agreement binding all countries to the same standard, some groups of nations formed common currency areas, the most successful being the Latin Monetary Union of 1865 and the Scandinavian Monetary Union of 1873.

Among the proximate sources that aim to explain this staggered rhythm of adoption are the Franco-Prussian war and the defensive monetary strategy of France against the announced conversion of the new German Empire to gold (Flandreau, 1996), the demonetisation of silver by the US in 1873 (Friedman, 1990) and the rise in world silver production in the 1860s concomitant with a reduction in demand from Asia, one of its traditional markets (Flandreau, 2004).

The logic of network externalities is one of increasing returns. The larger the number of countries on gold and the more central they were to the trade and finance networks, the greater the gains to other nations from joining. The central role of France and Germany in the European trade and finance networks means that the scale of the move in 1873 is not entirely apparent from Figure 1, which only counts countries and abstracts from their size or importance. Most authors effectively date the start of the international gold standard from 1873, once the European core of nations had joined. Contemporaries were well aware of these externalities. For instance, the Swiss representative to the monetary conference of 1867 duly stated that although Switzerland itself preferred an international regime based on gold, its decision was conditioned by the preference of France, then still a bimetallic nation.[3] Broch, the Norwegian representative, equally stated that as 'the trade of the United Kingdoms [Sweden-Norway] was mainly done with Germany, especially through Hamburg, their joining a monetary union would be necessarily subordinated to a previous accession by the North of Germany.'[4]

Figure 1 here.

In these statements we can see the logic of the trade gains from exchange rate stability invoked today about monetary unions (Rose & Glick, 2016). Indeed, the evidence about exchange rate volatility appears to confirm this association. Figure 2 represents a proxy for exchange rate stability: the coefficient of variation of monthly exchange rates against the central gold currency (sterling). We separated currencies by their regime and represent in the figure the median coefficient of variation by regime. This exercise has a couple of obvious biases with contradictory effects. First, by taking sterling as the *numéraire* it ignores that countries mostly trading outside the gold bloc could still attain exchange rate stability if sharing the same monetary regimes of their trading partners. Nevertheless, it reveals a clear hierarchy in terms of stability of the four monetary regimes. Interestingly, gold gains

[3] International Monetary Conference (1867), p. 44.
[4] International Monetary Conference (1867), p. 22.

ground against silver and bimetallic standards only after the scramble of the 1870s. The decreasing number of countries outside gold after that decade paid a clear price in terms of exchange rate uncertainty when trading with nations on gold. The volatility of paper regimes remains essentially unaltered throughout the period.[5] However, the volatility of silver currencies increases significantly since the early 1870s. In particular, the three spikes in 1890, 1893 and 1897 coincide with large changes in the market price of silver relative to gold. The second problem with Figure 2 is that it underestimates the underlying volatility of the different currency regimes due to the self-selection of countries into monetary regimes. Some of the countries that chose to remain outside gold were able to maintain relative stability through other means e.g. central bank intervention in the FX market, as in the cases of Austria-Hungary or Italy that remained on paper standards for substantial periods (Jobst, 2009; Tattara, 1999). This is even more obvious in the case of bimetallic regimes, which were abandoned by almost all countries by the turn of the century, with the exception of Venezuela and Bulgaria. Bulgaria was the last country to formally maintain this standard but despite that was able to retain a remarkable stability against foreign gold currencies thanks to a combination of good luck (positive trade balances) and domestic monetary measures (Dimitrova & Ivanov, 2014).

Figure 2 here.

The empirical literature on the gold standard has sought to quantify the magnitude of the network effects of trade and gold pegs. The effect of sharing the same currency arrangements on trade between dyads has been measured in the context of gravity models. Both López-Córdova & Meissner (2003) and Flandreau & Maurel (2005) find that countries on gold traded by at least 30% more with each other than with nations not on gold. There is however also evidence of reverse causality, as countries that traded extensively with other countries on gold adopted the golden peg sooner (Meissner, 2005). Trade links were far from the only 'permissive' condition for countries to join gold, but this raises an endogeneity problem, which is only imperfectly addressed by the use of the exogenous (gravity-driven) component of trade. Meissner (2005) also shows that the resilience of domestic financial systems was crucial to allow countries to peg to gold, whilst an excessive burden of debt delayed the adoption of this regime.[6]

[5]With the exception of an inflationary bout in 1898 concentrated in Portugal, Brazil and Spain.

[6]An earlier literature also tried to establish a link between gold adoption and lower

The expected trade gains are not the only potential source of endogeneity. Another strand of the literature has focused on the stability properties of the bimetallic regime, which had been favoured by the main trading nations (with the exception of the UK) until the 1870s (Flandreau, 2004). This line of inquiry tends to show, based on GE models, that the bimetallic regime, contrary to the intuition from Gresham's law, was perfectly able to maintain a stable relation between the market prices of gold and silver and, more importantly, deliver domestic price stability as well (Flandreau, 1996; Velde & Weber, 2000). Notwithstanding, the same models show that the demonetisation of silver by three of the largest economies in the 1870s (France, Germany and the US) made the system unstable and accelerated the scramble for gold by other nations which could not afford the monetary instability from holding on to silver (Meissner, 2015; Morys, 2015).[7]

The conclusion that we can retain from this review is that, in the absence of natural experiments, identification is hard to argue. Mitchener & Voth (2011) focus on the trade relations of Asian colonies precisely because they had no choice but to adopt the monetary regime imposed by their European colonisers. Consequently, the choice of exchange rate regime for colonies should reflect less the expectation of the gains from joining a common currency regime. This comes as close to a natural experiment as has been found in this literature and the authors still find a large positive trade effect for colonies that changed to gold prior to World War I.

Apart from the 'large country' status, there are two further threats to identification of causal relations in networks with traditional statistical methods. The first is the already mentioned clustering of the timings when countries joined the peg. As the majority of nations in the European core joined during a relatively short interval in the 1870s, it is not clear whether the identification in the existing regressions comes from a timing effect (e.g. a common shock) or from the fact that other nations were close, in economic terms, to these core countries (the network externalities). Figure 3 illustrates the problem by plotting the spatial autocorrelation measure devised

spreads on international borrowing (Bordo & Rockoff, 1996). Even though this direct link has been severely qualified since (Mitchener & Weidenmier, 2015), financial openness and the choice of exchange rate regimes were certainly connected, albeit in a more nuanced way. Bordo & Flandreau (2003) explain how only financially mature nations were able to borrow in foreign currencies and retain a credible peg to gold. Financially 'immature' countries were torn between the dangers of 'original sin' and the the 'fear of floating' (Hausman et al., 2001; Calvo & Reinhart, 2002).

[7]However, Fernholz et al. (2014) develop a DSGE model of the global economy, which when calibrated to 19th century conditions, implies that silver only stopped working as a global price anchor in the 1890s.

by Moran (1948) and applied to the exchange rate regimes in our sample of nations.[8]

Figure 3 here.

In correspondence with Figure 1, Moran's I starts significantly positive in the 1860s, which illustrates how the strength of network externalities prevented major changes in exchange rate regimes in this period, notwithstanding the perceived 'monetary question' and the successive international conferences gathered to solve it. The coefficient becomes insignificant in the later half of the 1860s and jumps to positive and significant values in the 1870s, during the so-called 'scramble for gold.' This measure of spatial autocorrelation reverts back to insignificant values in the 1880s/ early 1890s and jumps again to positive territory in the turn of the century.[9]

The final threat to identification comes from the very structure of the network of nations engaged in international exchanges through trade and finance. In a network, the probability of a country establishing a link with another nation clearly depends on the existence of ties between other countries. A practical example in this context is the inclusion of the Most Favoured Nation (MFN) clause in some of the treaties, which directly conditioned trade agreements and related trade relationships on the agreements the involved countries had with third parties. This then implies that the assumption of independently drawn country dyads must be violated, as the probability of a tie change is endogenous to the the current structure of the *whole* network. It is to try and address this issue that we turn to the methods of empirical network analysis, described in the next section.

3. Method

The SIENA, Simulation Investigation for Empirical Network Analysis, methodology has been recently developed by Steglich et al. (2010) to address situations of endogeneity involving network structures between actors. The main idea is to simulate the co-evolution of network and behaviour over time and use this to conduct statistical analysis of repeated observations of networks according to the Stochastic Actor-oriented Model.[10]

[8]Note that, to be consistent with our estimated model, we define contiguity by the network of trade relations, rather than by geographic distance.

[9]The coefficient is bounded between -1 (perfect negative spatial autocorrelation) and +1 (perfect positive spatial autocorrelation). The dashed lines in Figure 3 represent the confidence interval of the coefficient.

[10]The description in this section is closely based on the exposition in Manger & Pickup (2016) as well as in the underlying works of Steglich et al. (2010) and Snijders et al. (2010).

We estimate the model with a routine written for R, RSiena, which uses a method-of-moments procedure operationalized through repeated computer simulation to perform estimation. The basic starting point is to incorporate a wide range of mechanisms into the formation and development of the network structure to identify their respective effects onto tie formation and dissolution. This is expanded by incorporating behaviour changes, i.e. specific actor characteristics, to the set-up which adds a potential mutual dependence between ties and behaviour. To address this endogeneity problem the approach shifts the conceptual model from treating the observations over time as a series of discrete choices to a continuous process whose state is observed at specific time points. The network and each actor's behaviour are therefore taken as evolving continuously over each time period, and their simultaneous modelling allows to account for mutual dependencies and multiple changes between the points in time at which the states of the network and the behaviour are observed. An important restriction of this method, at the moment, is that it can only deal with count ordered variables for behaviour and binary definitions of the network. So long as the behaviour under investigation can be ranked, the first issue is not a great limitation. In our case, we will work with a ranked definition of exchange rate stability to define behaviour as the choice of exchange rate regime (see Figure 2). The definition of the binary trade links will be more restrictive, as discussed below in section 4.

Structurally, the modelling of mechanisms includes actor, dyadic and network structure effects. The first are based on particular characteristics of the actors, e.g. GDP in the context of countries as actors, which makes them equivalent to regular explanatory variables in a standard regression set-up. Dyadic effects are based on characteristics and covariates of pairs of actors. These can be direct tie variables, for example distance between two countries, or interacted actor variables, as the ratio of two countries' GDP. These links between actors can be ordered and directed, consequently allowing these dyadic effects to be potentially asymmetric. Finally, network structure covariates state the structural position of each actor within the network, for example the number of countries one is linked to.

Changes in the network as well as the behavioural status of individual actors are modelled as the outcome of a two-step process comprising two sub-processes; the first process governs when the possibility to change the network or behaviour arises for an actor, while the second then determines whether an actual change happens, once the opportunity arises. The first is governed by a rate function while the second is determined by an objective function. The rate function is similar to a hazard rate function in a survival analysis set-up and determines the probability that the actor can make a change at any given point in time. Once the possibility of a change arises the objective function determines whether a change increases the utility of the actor and will consequently be implemented. There are separate rate functions for network and behaviour, which are assumed independent from each other, such that the opportunity to change a behaviour will never arise at exactly the same moment as the opportunity to change the network.

Formally, the rate functions, which determine the waiting times until the next opportunity for change, are modelled by an exponential process with the following density function:

$$g_i(t) = \lambda e^{-\lambda t}, t > 0 \tag{1}$$

where $\lambda = \sum_i(\lambda_i^Z + \lambda_i^X)$ with λ_i^Z and λ_i^X as actor-specific (and possibly period-specific) parameters for the behaviour rate and network rate functions, respectively. This formulation implies that the probability that the next possible change actor i can make is a behavioural one is λ_i^Z/λ, and for a tie change λ_i^X/λ.

Once an actor gets an opportunity to make a change, the respective objective function determines which change (if any) maximizes the utility of the actor.[11] Starting from the current network structure, the actor has three possible actions with respect to each other actor in the network: initiate a new tie, dissolve an existing tie or retain the existing network without making a change. If there are n actors this then implies n possible actions consisting of changes in $(n-1)$ ties to other actors plus the retention of the existing structure. Formally, the network objective function, which includes the mechanisms modelled with network structure, actor and dyadic covariates, is given by:

$$f_i^X(\beta, \mathbf{x}, \mathbf{z}) = \sum_{\mathbf{k=1}}^{\mathbf{m_1}} \beta_k^X \mathbf{s}_{ik}^X(\mathbf{x}, \mathbf{z}) \tag{2}$$

Following generalized linear statistical models, this function is assumed to be a linear combination of a set of *effects*, $s_{ik}^X(\mathbf{x}, \mathbf{z})$, which are functions defined on the state of the network and behavioural variables. Particular examples will be discussed in a later section. Statistical parameters β_k represent the importance of the respective effects so $f_i^X(\beta, \mathbf{x}, \mathbf{z})$ is the value of the objective function for actor i depending on the states $\mathbf{x}$ of the network and $\mathbf{z}$ of the behavioural variables.

Similarly to a multinomial logistic regression, this allows to calculate the probability of any single tie change shifting the network status from $\mathbf{x}$ to $\mathbf{x}'$.

[11] Consequently, the objective function in each case takes the state of the network or the behavioural values as given.

Given the parameters of the objective functions this probability is:[12]

$$P(x) = \frac{exp(f_i^X(\beta, \mathbf{x}', \mathbf{z})}{\sum_{x' \in C} exp(f_i^X(\beta, \mathbf{x}', \mathbf{z})} \tag{3}$$

In the case of a potential change in behaviour, the actor has three choices, namely increase, decrease or retain the value. As the behavioural variable is required to be discrete, the potential increase or decrease is limited to exactly one step up or down. This restriction to a single step change is similar to the restriction to a single tie change in the case of the network structure. Furthermore, the behaviour objective function is also similar in structure to its network counterpart:

$$f_i^Z(\beta, \mathbf{x}, \mathbf{z}) = \sum_{\mathbf{k=1}}^{\mathbf{m_2}} \beta_k^Z \mathbf{s}_{ik}^Z(\mathbf{x}, \mathbf{z}) \tag{4}$$

Indeed, it is possible that the s_{ik}^Z are the same as those in the network objective function, but this implies that the same effects and covariates drive the change in network ties and behaviour values. This is clearly not a reasonable assumption, so the two sets of effects will normally differ between the objective functions. Although the included effects differ, the probability for a particular change is formulated in the same way:

$$P(z) = \frac{exp(f_i^Z(\beta, \mathbf{x}, \mathbf{z}')}{\sum_{z' \in C} exp(f_i^Z(\beta, \mathbf{x}, \mathbf{z}')} \tag{5}$$

These functions are used in the simulation algorithm to execute the estimation. The idea is to sample parameter values with the goal of matching the characteristics of the simulated networks with those of the actual observed network. This estimation utilizes a Method of Moments approach, although a Maximum Likelihood as well as Bayesian alternative are also feasible. The algorithm converges to an estimate for each parameter value and associated standard error as well as a t-statistic for its convergence.[13]

The sign of the parameter values and the standard error indicate the direction of the effect of the associated mechanism as well as its statistical significance. The estimated parameters for each effect should be interpreted

[12] C is the set of all $n-1$ possible tie changes. This probability is defined for a directed network with a behavioural variable so tie x_{ij} can take the value 1 while x_{ji} is 0 (and vice versa). There are a number of possibilities to force the symmetry between x_{ij} and x_{ji} such that the network is undirected and ties are simple links between two actors.

[13] The latter provides a check whether the simulated values converged sufficiently close to the observed network values.

as log-odds ratios. The explanatory covariate variables are centred on their mean, so if they are held at this rate, the parameter estimates give the effect of an one-unit change in the mechanisms on the probability of an increase (or decrease) in the network (i.e. the number of ties) or of the behavioural value.

The intention behind the application of this methodology is to disentangle the mutual feedback between network structure and behaviour variables. We will use the empirical network methodology to study the relation between trade links and monetary regime change described in the previous section. As already mentioned, the issue here is that countries that share the same monetary regime (e.g. the gold standard) are likely to trade more, what is usually referred to as a *degree* effect; but, at the same time, a country more involved in international trade may be more likely to adopt the gold standard (a *selection* effect), especially if it trades with countries already on gold (an *influence* or *contagion* effect). The incorporation of specific mechanisms involving the network, behaviour, and additional external factors is designed to clarify the structure of the influence in each direction. It does not, however, guarantee that the estimation results are causal in the face of the underlying endogeneity problem. Nevertheless, it is indeed possible to interpret the results causally under a relatively mild set of assumptions about the nature and timing of the evolution of network and behaviour, which should be easily fulfilled in our case. They are:

- The observed network and behaviour are the outcomes of an underlying Markov process in continuous time. This is reasonable to assume as transition probabilities between states of the network (trade) or behaviour (monetary regimes) should depend on the starting state.

- The actors act independently of each other at any moment, conditional on the observed network, behaviour and covariates. This requires that there are no coordinated (simultaneous) changes in the network or behaviour by two or more actors.[14] Although not strictly impossible, this kind of joint action by two or more nations has little historical relevance. Indeed, as described in section 2, nations did not coordinate their choices of trade partners or of exchange rate regimes, despite all the effort of the several international monetary conferences gathered in the second half of the nineteenth century.

- The changes in the network are conditionally independent from the

[14] The requirement of a reciprocal agreement to form a tie does not violate this assumption.

changes in behaviour, which implies that there cannot be simultaneous changes in network ties and actor behaviour. This is more disputable, but it should be noted that the models are based on continuous time, so we do not make much harm to reality by assuming this condition.

- At any given time only one single tie can be changed and similarly behaviour can only be increased or decreased by one unit. This is also not a restrictive condition for the same reason. To wit: it does not preclude the possibility of a country changing its monetary standard by more than one level or creating or cancelling trade relations with more than one nation, since the rate functions are defined in continuous time, while we observe the left- and right-hand side variables only at annual frequency.

The particular nature of our research questions fits well within the described set-up of the methodology, including the assumptions required for causality. Trade relations provide a natural network structure between actors (countries). In this paper we characterise trade in two ways, as the network of formal trade treaties and as bilateral trade flows. The first variable implies a non-directed network since, by definition, trade treaties are a reciprocal tie between two nations. For the purpose of the second network, we measure trade as exports from one country to each of its trading partners, a directed network.The behaviour variable in our model is the choice of exchange rate regimes. This is coded as a count variable, and the panel nature of the data provides repeated observations of the evolving network and behaviour.

4. Estimation

4.1. Data

We run our model for a sample of 42 independent nations over 64 years (1850-1913). This long panel is not balanced because of missing data on covariates and also because some countries only enter the analysis at independence. The method deals with this source of attrition in a natural way by forcing the potential ties to these nations as 'structural zeroes', meaning that these ties are impossible until the country comes into existence as a sovereign. We concentrate exclusively on sovereigns because the model assumes that actors have autonomy to act in accordance with their own national interest. The full list of nations and their inclusion dates are listed on Table 1.

Table 1 here.

We do not run the model at a yearly frequency because there is a trade-off between precision of estimates and frequency of data. Similarly to a regression, if the left-hand side variable has small variance the model will not have a good fit. To increase the variance of trade link changes and monetary regime changes, we ran the model with biennial observations (32 time periods). Our model includes three dependent variables. The first is the exchange rate regime adopted by each country and, in particular, whether it joined the gold standard (behaviour). We then include two network variables: whether each pair of countries is connected by a trade agreement and/ or by actual trade flows.

The inclusion of two definitions of the trade network serves two purposes. First, it allows quantifying the relative strength of formal trade ties and actual trade flows in influencing the choice of exchange rate regimes. Second, it provides a natural testing ground for the mutual relation between trade agreements and actual trade. In particular, we will be able to test whether trade treaties created trade or, as argued in the recent literature, the wave of trade agreements in the 1860s came after the majority of unilateral trade liberalisation had been accomplished (Accominotti & Flandreau, 2008; Tena et al., 2012).

We classify the exchange rate arrangements into four possible values: paper currencies (without a formal metallic backing), silver standards, bimetallic standards and gold standards. We then coded these four regimes into our behavioural variable, which is ordinal and takes values increasing in the degree of exchange rate stability: 1 for paper regimes, 2 for silver, 3 for bimetallic and 4 for gold. The underlying classification was done by the authors based on the following sources: Accominotti et al. (2011), Bae & Bailey (2003), Esteves (2007), Ferguson & Schularick (2006), Leavens (1939), Meissner (2005), Pick & Sédillot (1971), Vv.Aa. (2014), and Young (1925). Even though this ordering of exchange rate stability is time-varying (see Figure 2) and depends on country idiosyncratic characteristics (e.g. frequency of real shocks), we believe that it gives a good representation of the order of monetary choices facing countries in the 19th century, especially after the 1870s.[15] Moreover, we also ran the model with a tripartite classification of exchange rate regimes (paper – silver or bimetallism – gold) and the results

[15]The retention of bimetallism by large countries until then effectively stabilised the gold/silver price ratio minimising the destabilising impact of large gold or silver discoveries according to Gresham's law. After 1872, the double shock of widespread demonetisation of silver and large silver discoveries, which quadrupled world production, meant that holding on to a silver standard implied a systematic tendency toward currency depreciation accompanied by greater exchange rate volatility.

were very similar.

The information on the treaty agreements network comes from Robert Pahre's trade agreement database, which covers the full time period (Pahre, 2007). It contains treaties between sovereign nations which directly concern trade arrangements between the two involved countries. The range of matters addressed in these treaties is fairly wide, ranging from shipping rights, small import concessions, most-favoured nation arrangements to free trade treaties. In turning the data set into the variables used in the network part of our model, we make two simplifying, related assumptions. First, we only record whether a trade treaty was in force between two states, the actual content does not influence the coding of the binary variable. Second, we also do not distinguish whether the treaty was an arrangement clearly benefiting both sides or whether it was just one side making concessions. This implies that we do not distinguish between regular trade treaties among mutually consenting nations and the so-called 'unequal treaties' that were imposed on a number of developing and emerging nations in the course of the 19th century (Findlay & O'Rourke, 2007).

The data on actual trade flows comes from two large repositories of bilateral trade flows: the RICardo and the TRADHIST databases (Dedinger & Girard, 2016; Fouquin & Hugot, 2016).[16] Coding these trade flows into a network of dyadic relations also involved a restriction on the use of the original data. Since the model requires that the network links be entered as binary values (link, no link), we censored the data on exports to only cover trade relations that cleared a minimum threshold of trade intensity. This threshold was set at 0.5% of the origin country's exports. This means that we only code a trade link from country A to country B in a given year, if A sells to B at least 0.5% of its exports on that year. The threshold was not arbitrarily fixed, but corresponds to the median of bilateral trade shares in our database. As is well known, the distribution of trade shares is very skewed to the right, so that in setting such a low bar we are effectively capturing the extensive margin of trade, rather than its intensive margin.[17] In a future version of the paper we will investigate other definitions of trade to capture the intensive margin as well. Specifically, we will distinguish three

[16] Available at, respectively, http://ricardo.medialab.sciences-po.fr/#/ and http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=32.

[17] The Hirschman-Herfindhal index of bilateral trade shares averages 0.297, with a minimum of 0.076 (Great Britain) and a maximum of 0.81 (Honduras). Alternatively, the top ten trade partners absorbed on average 97% of all exports of each nation, with a minimum of 75% in the case of Britain, the country with most diversified trade network in this period.

trade networks involving minor or occasional trade partners, average trade partners and major trade relations.

As the dependent variables, the covariates can be in two forms, either using dyadic data resembling network ties or monadic (country-specific) data. Dyadic variables include time-invariant geographic factors, in particular the distance between two countries and whether they are contiguous to each other. Distance is measured as the distance in kilometres between (modern) capitals and is taken from the CEPII's GeoDist database (Mayer & Zignano, 2011). Contiguity is a binary indicator based on the classification by the Correlates of War project (Stinnet et al., 2002). Another time-invariant dyadic covariate is based on the languages spoken in each country pair. The variable is coded as one if both countries have the same official language, and zero if not from the data in in the CEPII's language dataset (Melitz & Toubal, 2012). The final two dyadic covariates are time-variant binary indicators for whether two countries were in a formal political alliance or were at war with each other, as coded by the Correlates of War project (Sarkees & Wayman, 2010; Gibler, 2009).

The monadic variables include time-variant country characteristics as well as common time effects.[18] Our choice of variables is driven by the several drivers of monetary unification during the 19th century identified in section 2. To capture long-term structural forces we include real GDP per capita and the levels of industrialisation and urbanisation in each country. Real per capita GDP data is taken from Barro & Ursúa (2008) and other sources. Information about the level of industrialisation is incorporated by including the share of secondary sector employment as given by Banks (1976). The degree of urbanisation is measured as the share of the total population living in cities above 100,000 also from Banks (1976).

Among the proximate drivers of gold adoption, we include two measures of the fiscal space of individual governments and the ratio of the market prices of gold and silver (a time effect). The two fiscal variables, which control for the 'fiscal maturity' of each nation, are the share of external debt (or debt repayable in FX) in the total debt stock of each country and the ratio between debt service payments and total government revenue. The data on these variables were compiled by the authors. The market prices of gold and silver bullion in London were taken from Officer & Williamson (2016) and NBER (n.d.). Finally, we also control for the political system as proxied by the PolityIV score (Marshall et al., 2014). We include this variable to control

[18]To estimate a common effect we need to drop at least one country-period observation. We chose to do drop Cuba and Bulgaria.

for the political economy theories about the adoption of gold, particularly the prevalence of restricted franchises in the prewar (Eichengreen, 1992). Table 2 lists the summary statistics for all left- and right-hand side variables included in the model.

Table 2 here.

4.2. Specification

We now incorporate the variables described in the previous section into a number of mechanisms, which then constitute six separate functions. For each of the three outcomes (two trade networks and monetary standard), we estimate two functions: one rate function determining the opportunity to make a change in the respective outcome and the objective function, which determines which change (if at all) should be made when the opportunity arises.

4.2.1. Monetary Standard

The *rate function* for changes to the monetary standard contains the basic setup of any rate function, namely, a constant for each period between observations. As we did not include any further mechanisms in the rate function, the estimates for the time-varying rate represent the expected number of opportunities for changing the monetary standard during the respective time period. We will not report the estimate of this parameter λ^Z, because it does not have a natural economic interpretation.

The *objective function* underlies the decision once the opportunity to make a change to the monetary standard arises. The options are the retention of the existing standard, a change 'up' and a change 'down'. Up and down refer to the ordering of the different standards, from paper (1) to silver (2), bimetallism (3) and gold (4). If, e.g., a country is on a silver standard, the options are to retain that standard, move 'up' to bimetallism or 'down' to a paper standard.

We include three types of mechanisms in the objective function. The first is based on the existing monetary standard, which is introduced in a *linear* as well as *quadratic* form. These two effects test whether the existing monetary standard influences the decision to change regime. If so, the range of possible results would either be a push toward the extremes (gold or paper) or toward the mean, i.e. either silver or bimetallism. Another way of thinking about these effects is to say that they correspond to a time trend (linear and quadratic). The second type of mechanisms combines the existing trade network and the monetary standards of each nation's trade partners. We include two effects of this type, the first of which measures the monetary regime of trade partners or treaty co-signatories. The second effect is similar but focuses on indirect trade links. A country A by signing a treaty with country B can gain access to B's trade partners. Similarly, exporting to B can be a way for A to re-export its goods to B's partners. To capture the impact of these indirect links on A's choice of a monetary standard, we include a mechanism that captures the monetary regime of all indirect trade partners of A.

These two effects are our main variables of interest in the behavioural side of the model, as they test whether trade links were an incentive for countries to join the same monetary standards of their trading partners. The third type of mechanisms includes the country-specific monadic variables: *GDP*, *industry share*, *urbanization*, the *PolityIV score*, the *foreign debt share* and the *debt service ratio*, as well as a common time effect: the *metal ratio* of the market prices of gold and silver bullion.

4.2.2. Trade Networks

The rate functions of each of the two trade networks incorporate the same period effects as the monetary standard and yields a parameter λ^X, which we do not report.

The objective function expresses three options for change (given the chance), namely, to retain the existing network, to add one link with another country or to sever an existing one. We include four types of mechanisms in this function. The first type is again based on the outcome itself, and includes four effects. The first is the *degree* of involvement in the network, i.e the number of trade agreements or trade links a country has in force at the time. The second, only present in the trade flows network, tests for the impact of *reciprocity* in trade flows, i.e. whether countries tend to establish more bilateral than unilateral trade ties. The third effect is the number of *indirect trade partners* that could be opened up by signing a further trade treaty with or exporting goods to an additional nation. The fourth effect tests for network closure. Practically, this mechanism tests whether a country is more (or less) likely to open up a trade link (or sign a treaty) with another country if the two are already connected through a common third country. If these *Transitive triads* were inferior to direct links we would expect this effect to have a positive impact on the establishment of direct trade connections.

The second type of mechanisms is based on the monetary standards of other countries, our main variables of interest. The first of three effects in this category tests whether the *monetary system (domestic)* of each nation matters absolutely, i.e. whether a country is more (or less) likely to establish a trade link with another nation if it has a 'higher' monetary standard.

The second effect is similar but based on the the *monetary system (partner)*, i.e. it tests whether a nation's trade network is influenced by the currency arrangements of its potential trade partners. Finally, the third effect is restricted to measuring the impact of having potential trade partners using the *same currency* regime. This effect is the counterpart to the several gravity studies which find that countries sharing the same monetary standard trade more.

The third type of mechanism tests for the reciprocal effect of pre-existing trade flows on the likelihood of establishing new trade agreements and of trade agreements on the likelihood of starting to trade with the signatories. As mentioned, recent literature has found more evidence of the former effect (trade leads to treaties) than of the latter. Finally, we include as fourth class of mechanisms, the direct effect of dyad-specific covariates: *contiguity* between each pair of countries, *distance*, common *language* and whether the countries were part of a political *alliance* or were at *war*.

5. Results

Table 3 provides the estimates of each mechanism included in the objective functions. The results for the mechanism parameters of the three objective functions can be interpreted similarly to the coefficients resulting from a logistic regression. In the case of the behaviour objective function, the exponentiated coefficients define the multiplicative increase in the probability of 'moving up' one level in the order of monetary regimes given a one-unit increase in the respective covariate.

Table 3 here.

The significant linear and quadratic shape parameters of the monetary standard mechanism indicate that the evolution of monetary regimes had considerable persistence. Specifically, the relative probabilities of 'moving up' the monetary regimes scale is higher than retaining the current one. In other words, there is evidence of a deterministic trend toward the 'highest' standard in our classification, gold. This accords with the interpretations of the rush to gold, such as the spread of the 'gold ideology' and is visually consistent with Figure 1.

The pattern of results for the two network-based mechanisms is interesting. There is a strong influence of direct trade partners on the choice of exchange regime. The coefficient of the variable *Standard of trade partners* implies that a country is 25% more likely to trade with a nation with a 'higher' currency regime than its own.[19] than with a nation with the same of 'lower' currency. In the case of trade treaties, the effect is quantitatively much smaller (4%) and only applies through indirect partners. Whilst the first result was expected, the second is more puzzling and bears some more research. Taken at face value, this result would mean that countries signed treaties more with a view to gain indirect access to markets other than the market of their co-signatories. Three monadic covariates have a statistically significant influence on the odds of changing monetary standards.The share of debt held abroad has a strong negative influence, shifting countries from gold towards silver and paper. To put this estimate in perspective, a one standard deviation increase in the foreign debt share (32 percentage points, see Table 2) makes the retention of the existing standard 58% less likely than a down-shift of the monetary standard. The corresponding effect of a one standard deviation increase in the debt service ratio, leads to a 3.5% decrease in the relative probability of an upward-shift in the monetary standard. Finally, wealthier nations rushed faster toward gold. A one standard deviation increase in per capita GDP made an upward shift in monetary regimes twice more likely than a retention or downward shift.

The estimated parameters for the objective function underlying the two trade networks similarly compare the relative probabilities for no change in the network with the addition (or removal) of a particular network tie.[20]

Starting with the trade agreements network, the negative degree effect indicates that the more trade treaties a country has in force, the less likely it is to add another one. The positive effect of the 'transitive triads' mechanism however implies that the probability of adding a tie increases if that tie creates a triad, i.e. if the two countries have already existing trade treaties with a common third country. A similar effect is evident in the third effect: countries are more likely to seek a trade agreement with nations that have more trade partners. The signs of the parameters for contiguity and distance are consistent with standard gravity arguments. The relative probability of adding a particular tie increases if the two countries are contiguous or if they have geographically closer. For instance, contiguity increases this relative probability by 25.6%. Strangely enough, countries sharing the same language are 21.5% less likely to sign a trade treaty. Even though this an effect conditional on the other network mechanisms, it may reflect the importance

[19]Equivalently, the probability of trading with a nation on a 'lower' regime is 20% lower than trading with its own regime.

[20]It is consequently also feasible to compare the relative probabilities between two potential ties or any other combination of two changes of the network involving a single modification.

of 'North-South' trade relations during the nineteenth century for emerging economies (Findlay & O'Rourke, 2007). Furthermore, as our sample only includes independent nations, the American continent is over-represented, with 43% of the nations included coming from Portuguese- and Spanish-speaking Central and South America.

The third group of mechanisms involves the monetary standards of the country itself, as well as of possible treaty partners. The first effect *Monetary standard (Domestic)* implies that a country with a 'higher' monetary standard had a 8.3% higher probability of signing a trade treaty. Apparently, the monetary standard of potential signatories did not matter nor, more interestingly, whether the two potential signatories shared the same currency regime. This result seems to go against the extensive evidence about the gains from trade from shared monetary regimes. However, we do not wish to emphasise this result at this stage, because it is based on the network of trade treaties, rather than actual trade flows. As other authors have shown, trade liberalisation through treaties is an imperfect predictor of trade growth before 1913 (Accominotti & Flandreau, 2008; Tena et al., 2012). Finally, there is no effect of pre-existing trade flows on the likelihood of two nations signing a trade agreement.

In the trade flows network all covariates are significant and mostly have the expected signs. The degree effect is also negative, consistent with the stylized fact that international trade networks tend to be concentrated in relatively small number of partners. Moreover, there is a strong effect of reciprocal trade flows, perhaps suggesting that most nations were not able to retain unbalanced trade relations for long. The effect of transitive triads is also positive as in the trade agreement network, but there is now negative effect of the number of indirect trade partners. Both effects imply that indirectly gaining access to other markets via re-exports was a inferior choice. All the dyadic effects have the expected sign. In particular, common language is now positive.[21] To directly test for the mass variable in the gravity framework, we also included GDP per capita, which has the expected positive sign.[22]

The three effects dependent on the monetary regimes of potential trade partners have striking results. First, nations with 'higher' currency regimes have a lower likelihood of establishing new trade links. As mentioned before,

[21]The war variable came systematically insignificant and was dropped.

[22]Note that since GDP is a constant for each nation in each year, the GDP of each partner on that year effectively works as the interaction term between the two nations' GDPs. A one standard deviation increase in the partners' GDP raises the likelihood of a new trade link by 1%.

this is purely an extensive margin result, as we do not control yet for the volume of trade. It seems to suggest that emerging nations expanded the extensive margin of their trade networks more than the more established trading nations in the core of Europe.In contrast, the monetary standard of potential partners has a strong positive effect on the creation of new trade links. A country is 15.6% more likely to trade with another nation with a 'higher' currency regime than with a 'lower' regime. But the real surprising result is the strong and negative coefficient on same monetary regime: nations sharing the same regime, all else equal, were 43.7% less likely to start trading. Rather than overturning the similar result for the trade agreements network, this result reinforces it and may question the conclusions in the extensive literature on the trade gains from currency unions. Nevertheless, we need to incorporate the dimension of trade intensity to verify this interpretation.

Another result that goes against the existing literature on 19th century trade liberalisation is the significant and strong effect of treaty agreements on trade: two countries connected by a trade agreement are 34% more likely to start trading or continue to trade than if they have no agreement. There is, however, one possibility of reconciling this result with the literature (Accominotti & Flandreau, 2008; Tena et al., 2012). If the variance in the intensive margin of trade was smaller than in the extensive margin, it is possible that previous studies, based on gravity regressions, might have correctly found no effect of trade treaties on trade volumes among nations that were already trading, whilst missing the impact of those treaties in creating new trade links.

6. Conclusion

The importance of strategic externalities in the network of currencies in the gold standard has been established in the literature (Flandreau & Jost, 2009). This paper introduces a novel methodology to identify the nexus of externalities between trade links and exchange rate regime choices during the rise of the classical gold standard. Dynamic network models are a natural setting to estimate the co-evolution of networks and behaviours and allow for a causal interpretation of the mutual feedback effects under a relatively mild set of assumptions.

The specification and results are still at a preliminary stage, but the evidence is suggestive of a stronger effect of pre-existing trade on the choice of monetary regimes than the reverse effect of monetary standards on the pattern of trade links. In the model, the trade network (both agreements and actual flows) acts through shaping the externalities imposed by other countries' monetary standards on the domestic value of adopting different monetary regimes. More work is necessary to incorporate trade intensity to the current definition of trade links that only captures the extensive margin of trade. Nevertheless, the results in this paper qualify the consistent evidence from gravity studies about the large and significant effect of monetary standards (and especially gold) on trade. In network analysis this would be because the selection and contagion effects (i.e. the tendency for more open countries to adopt stable exchange rate regimes, such as gold) dominated the degree effect that leads to greater trade between countries with the same exchange rate or currency.

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Table 1: **Countries Included in Analysis**

Argentina	Cuba (1898)	Italy (1862)	Russia
Austria-Hungary	Denmark	Japan	Serbia (1879)
Belgium	Dominican Rep	Mexico	Spain
Bolivia	Ecuador	Netherlands	Sweeden
Brazil	El Salvador	Nicaragua	Switzerland
Bulgaria (1879)	France	Norway	Turkey
Canada	Germany	Paraguay	United States
Chile	Great Britain	Persia	Uruguay
China	Greece	Peru	Venezuela
Colombia	Guatemala	Portugal	
Costa Rica	Honduras	Romania (1879)	

Table 2: **Summary Statistics**

Variable	Mean	St.Dev	Median	Min	Max
Monetary Standard	2.54	1.12	2	1	4
Treaties†	2.15	1.7	1.75	0.14	7.78
Trade links†	16.03	6.30	14.59	0.73	28.12
Contiguity	0.07	0.25	0	0	1
Distance	6.67	4.37	7.5	0.17	19.3
Language	0.19	0.39	0	0	1
War	0.00	0.05	0	0	1
GDPpc	1.97	1.08	1.78	0.41	6.89
PolityIV	8.73	5.78	7	0	20
Urbanization	32	106	1	1	687
Industry	8	41	1	1	339
Foreign Debt Share	0.31	0.32	0.23	0	1.05
Debt Service	0.22	0.12	0.21	0.001	0.68
Metal Ratio	22.54	8.68	18.63	15.14	42.63

†Average over time by country. Note: PolityIV has been shifted by 10 to a range of 0 to 20. Urbanization and Industry are defined in 1/1000*s* so 100 equals 10%.

Table 3: **Estimation Results**

Network - Treaties	Log odds	S.E.
Network degree	-0.852	0.0734 ***
Transitive triads	0.243	0.0328 ***
Nr indirect partners	0.116	0.0286 ***
Contiguity	0.228	0.1304 **
Distance	-0.027	0.0104 ***
Language	-0.243	0.1085 **
Alliance	0.243	0.2387
War	0.447	0.4598
Money (domestic)	0.080	0.0483 **
Same money	-0.028	0.087
Trade partner	0.135	0.1122
Network - Trade	Log odds	S.E.
Network degree	-1.9474	0.0756 ***
Reciprocity	1.5725	0.0673 ***
Transitive triads	0.108	0.0085 ***
Nr indirect partners	-0.0846	0.0278 ***
Contiguity	0.5691	0.1022 ***
Distance	-0.0498	0.0075 ***
Language	0.12	0.0751 **
Alliance	0.4228	0.2122 *
GDPpc	0.0093	0.0007 ***
Money (domestic)	-0.0773	0.0262 ***
Money (partner)	0.1452	0.0251 ***
Same money	-0.5753	0.1018 ***
Treaty partner	0.2925	0.0784 ***
Behaviour - Exchange Regimes	Log odds	S.E.
Linear shape	0.868	0.2460 ***
Quadratic shape	0.670	0.1525 ***
Standard of treaty partners	0.146	0.2446
Nr indirect treaty partners	0.039	0.0204 **
Standard of trade partners	0.222	0.1170 **
Nr indirect trade partners	-0.013	0.0092
GDPpc	0.654	0.3260 **
Polity IV	0.034	0.0293
Industrialisation	-0.001	0.0095
Foreign Debt	-2.704	1.1404 ***
Debt Service	-0.293	0.1823 **
Metal Ratio	-0.018	0.0281

Figure 1: **Monetary Regimes, 1850-1913**

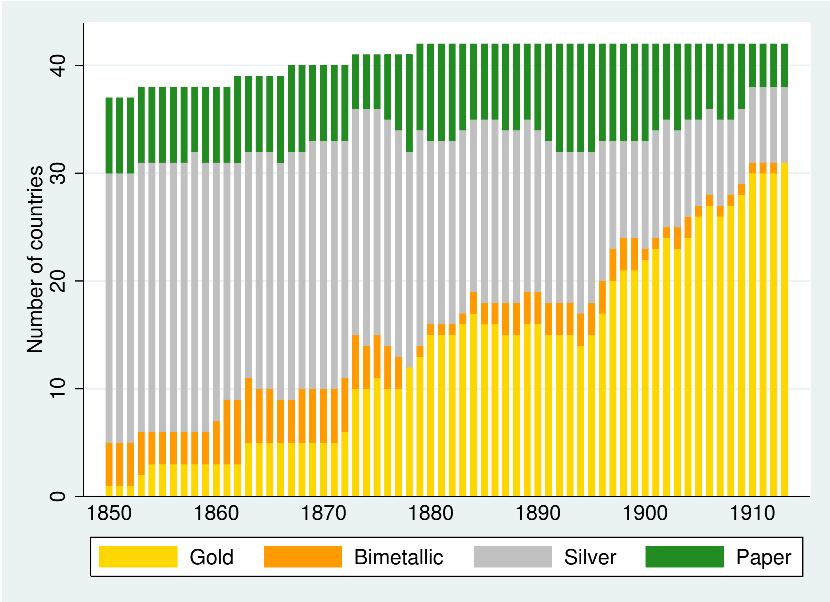

Figure 2: **Exchange Rate Volatility, 1850-1913**

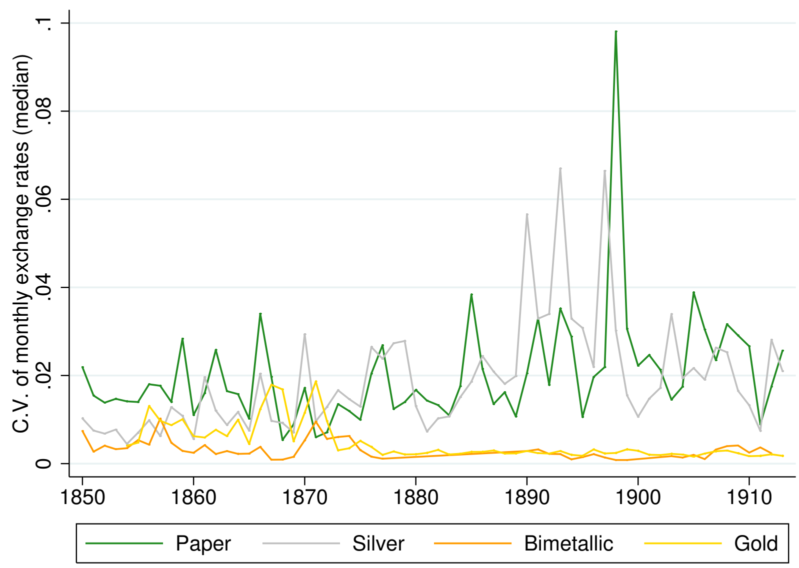

Figure 3: **Moran's I, 1850-1913**