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DOES THE PAST COUNT? SOVEREIGN DEBT DURING THE CLASSICAL GOLD STANDARD THROUGH THE LENSES OF MOVER STAYER AND MARKOV CHAIN MODELS

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ABSTRACT

We study sovereign debt markets behaviour during the Classical Gold Standard (CGS) Era (1880-1913), i.e. the first era of globalization characterized by free movement of capital and a fixed exchange rate regime. In particular we analyse both the issues of markets memory and the degree of confidence in sovereign debt markets by means of three stochastic models: Markov Chain (MC), Mover Stayer (MS) and Non Homogeneous Markov Chain (NHMC) estimated on two-state transition matrices of countries switching from sound to distressed. Markov Chain and Mover Stayer models beat the Non Homogeneous Markov Chain in fitting the data in the CGS period (1880-1913). This result implies both the short memory of the markets towards countries' default history and an increased level of certainty which enables countries to better attract capital from lenders. The lessons learnt from the CGS period could also be relevant to understand sovereign debt markets in the Eurozone today given the striking similarities between the two periods.

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1. INTRODUCTION

In the literature on sovereign debt, reputation building for countries often matters (Tomz and Wright, 2007). Many studies have in fact shown that sovereigns with a bad history of default typically have been excluded from the access of future lines of credit. Reinhart and Rogoff (2009), studying centuries of default history of countries, have pointed out that the number of defaults is important and that countries, which have defaulted many times in the past, most probably will default again. This result makes a lot of sense if the whole history of countries is considered, but a different outcome might be present if one focuses on specific historical periods.

The purpose of this paper is to study the memory of the markets towards sovereign default during the CGS era (1880-1913). We find that studying the characteristics of sovereign debt markets in this particular period is interesting given the striking similarity of the CGS era to the Eurozone today. They both are periods of time in which exchange rates are fixed, capital moves without restrictions and they are both eras of globalization.

We show that during the CGS era markets' memory is short. The reputation of countries does not matter for the markets, i.e. the past history of countries does not increase their probability of default. This result, in contrast with the literature, which provides evidence on longer spans of time, means that investors operating at the time of the CGS era were confident. If default countries, during the period, could immediately graduate, i.e. have a renewed access to capitals, investors were judging the environment in which they were operating as a safe one.[1] This does not imply that countries were not defaulting during the CGS era (in 34 years the median annual percentage of countries in default is 14.3% with a peak of 33% in 1880), nor that the 'usual suspects', namely Latin American countries, did not have a leading role in characterizing the default episodes, but it means that investors were confident in buying Greek or Argentinian bonds (and thus making profits) basing their decision only on the present and most recent history of those countries.[2] The CGS era was thus a period in which investors were acting within a safe economic environment, proved by the fact that they were putting a certain level of trust on those economic conditions.

This paper is new to the literature for two reasons. First because it sheds light on the graduation, which is a different positive aspect of the CGS era, given that most of the literature has instead looked at the CGS as a credible monetary regime and at the advantage, in terms of interest spread reduction, for

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[1] It is beyond the scope of this analysis to understand why the environment of the CGS era was a safe one. It could be the CGS monetary regime, the favourable macroeconomic conditions of the Golden Age etc.

[2] Investors also in recent times (2017-2019) have based their investment decision in buying Greek bonds on the relative good performance of Greek fundamentals in the actual cycle and by trusting the economic environment of the Eurozone at that moment of time.

poor developing countries in joining the regime.[3] The second is the methodology we use which is new to the literature, i.e. we study the statistical properties of two-state annual transition matrices of countries switching from a ‘sound’ state to a ‘distressed’ state.

We test whether we can fit our observed transition matrices with the following stochastic Markov models: Markov Chain (MC), Mover Stayer (MS) and Non Homogeneous Markov Chain (NHMC). These models, which rose in the ’60, have been recently used for relevant economic applications in the fields of labor markets (Fougére and Kamionka, 2003; Baussola et al., 2019), credit and bond ratings migration (Jafry and Schuermann, 2004; Frydman and Kadam, 2004) and agricultural economics (Saint-Cyr and Piet, 2016). To our knowledge we are the first to apply these consolidated techniques to a relevant topic in economic history.

MC and MS guarantee two relevant properties. The first is the Markov property and a constant hazard function. The second is time homogeneity, which implies both stable conditional probability of defaulting over time and the convergence towards an equilibrium distribution. However, MC and MS differ in terms of spatial homogeneity. While MC guarantees both temporal and spatial homogeneity, MS guarantees only temporal homogeneity, intended as the tendency of different countries to evolve in the same way. In fact the MS model combines two groups of countries: the Movers and the Stayers. The former group is ruled by a classical Markov Chain, while the latter contains countries never moving from their state. Lastly NHMC does not guarantee any of these properties.

We find that the CGS era (1880-1913), differently from the Interwar Gold Exchange Standard (IGES) era (1925-1933), is governed by homogeneous time models (MC and MS). This result is particularly striking, given that the two models are able to fit the data well in such a long period of time (34 years). The fact that the two models (MC and MS) fit the CGS era well, imply that relevant economic properties characterize the sovereign default issue in the period.

The first, consequent to the Markov property, is that a country’s past history does not matter for the probability of default. Moreover a constant hazard function implies that, after having exited from default, the amount of time spent as sound does not influence the probability of becoming distressed. The second, consequent to time homogeneity, implies that the era is characterized by a low degree of uncertainty given that the probability of switching from a sound to a distress state and vice versa, does not change abruptly over time. This result is in line with the possibility of countries of having easy access to the capital markets in the CGS period.[4]

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[3] As far as we know the exception is Özler (1993) who studies defaults episodes in the period 1820-1929 and those after the 1930s. His findings are that ‘defaults prior to the 1930s do not have any impact on credit terms’ (p. 610), whereas ‘defaults of the 1930s and repayment problems of the postwar period, however, are found to have a statistically significant impact’.

[4] We run the same models in the Interwar Gold Exchange Standard Era and the same statistical properties do not apply, given that the NHMC model wins. The latter does not share stable conditional probabilities, convergence to equilibrium and constant hazard function

The rest of the paper is structured as follows. Section 2 and 3 outline the literature on sovereign default in historical perspective and the CGS era, Section 4 describes the dataset and provides an exploratory analysis, Sections 5, 6, and 7 report the statistical models and outline the main results. Section 8 concludes.

2. SOVEREIGN DEBT IN HISTORICAL PERSPECTIVE

Whether sovereign default events have short memory is studied in the literature mainly through how sovereign defaulters are punished. In particular whether they are punished through the exclusion from the access to future lines of credit.

From a theoretical perspective the seminal contribution by Eaton and Gersovitz (1981) argues that exclusion from access to futures lines of credit would be a deterrent to strategic default. Bulow and Rogoff (1989) react to this approach arguing instead that only the threat of direct punishment in the form of trade sanctions, embargoes or gunboat diplomacy could deter the sovereign from default. However the debate is still open as to whether sanctions, domestic or external, lead countries into debt spirals, and whether it would be in the best interest of creditors to postpone settlements with debtors, to prevent a collapse of the borrower's economy (Kovrijnykh and Szentes, 2007). Punishment (either in the form of exclusion from credit or direct sanction) is not necessarily included in all models of default, as in the models of 'debt as a contingent claim' à la Grossman and Van Huyck (1988) where default is an equilibrium phenomenon, and creditors 'forgive' defaulters when non-repayment is due to bad shocks affecting the economy.

From an empirical perspective studies explore the reaction of creditors towards the behaviour of countries with a poor record of debt repayments or default. An extensive empirical study of the behaviour of debtors countries is provided by Lindert and Morton (1989). These authors by focusing on ex-post realised returns to holding sovereign bonds in the period 1850-1983 find no evidence of excess returns, which signal the absence of punitive interest rates charged to countries with a poor record of debt repayment. Recently, the theoretical hypothesis à la Grossman and Van Huyck (1988) has found empirical support in Edwards (2015), who by investigating the behaviour of debtors default episodes, occurred between 1978 and 2010, finds that with few exceptions, notably Argentina in 2001, debtors' haircuts reflect bad shocks affecting the domestic economies. Özler (1993) investigate the impact of borrowers' repayment history on their ability to access credit markets and since during crises periods markets may be affected by panic, he studies defaults episodes in the period 1820-1929 and those after the 1930s. His findings are that 'defaults prior to the 1930s do not have any impact on credit terms' (p. 610), whereas 'defaults of the 1930s and repayment problems of the postwar period, however, are found to have a statistically significant impact'. This implies that defaulters of the post-WWII period are charged rates significantly higher than non-defaulters.

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with the other two models.

Regarding exclusion from financial markets, results from Gelos et al. (2011) seem to suggest that it lasts at least 4.7 years in the period that they have considered (1980-2007). More recent studies, as Cruces and Trebesch (2013), instead find that countries regain partial access to capital markets on average after 5.1 years after default and full access (i.e., when debt flows exceed one percent of GDP) 7.4 years after default. These measures are related to the years that it took to regain access to financial markets after the country has emerged from default. If to these figures we add the years that on average countries have been on default (i.e., 8 years according to Uribe and Schmitt-Grohé, 2017) then the previous figures become 13.1 and 15.4 years, respectively. But as documented in the empirical literature, exclusion (or not) from financial markets is only one of the possible costs of default, other potential costs are international trade sanctions (Rose, 2005, Martinez and Sandleris, 2011) output losses (Borensztein and Panizza, 2009), reputational spillovers (Cole and Kehoe, 1998). All these costs of defaults bring some authors as Reinhart and Rogoff (2009) to introduce the concept of serial defaulters. Serial defaults are typically associated with a vicious circle of default, higher risk premia, and thus interest rates, and eventually greater borrowing to service the increased cost of debt, which ends up in a spiral of debt. This makes it difficult for countries to graduate from default. Graduation only occurs when high growth takes place, but as the authors observe this is a rare event.

The problem of serial defaults in history is also studied, more recently, by Drelichman et al. (2011), who find that in some cases as with Philip II (1566-1600) creditors' losses were more than compensated by profits in normal times and by Asonuma (2016), that explains some stylized facts about serial defaults in the period 1978-2010, one of which is that 'Past defaulters are more likely to default again', with default probability for past defaulters higher than for non-defaulters.

3. THE CGS ERA

The years of the CGS era are characterized by a high degree of political stability, within many countries, joined by phases of strong confrontation between countries which lead in some cases to war as it is the case of US against Spain (1898), Japan against Russia (1905) and Italy against Turkey (1912).[5]

In spite of these episodes of international unrest, according to Daudin et al. (2010) the CGS era is characterized by some precise features: strong convergence of prices, between Europe, U.S. and Asia, for wheat, cotton, iron bars, pig iron, copper and other commodities; reduction of transport costs and growth of international trade. This period is considered as the First Era of Globalization (Bordo and Meissner, 2011) and despite the great variety of levels of adherence or non-adherence to the gold standard, it can be considered, to use Ford (1989) words, as 'a form of solar system with London at the center'.

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[5] In some years the international tension is high even if it does not give rise to a war, as it is the case of the trade war between Italy and France, that of Russia with Austria for the Balkans and finally the one between the UK and Germany.

These economic features, joined with the high degree of political stability, spur capital market integration, which is advocated by Eichengreen (1992) as the channel through which savings flow from surplus to deficit countries. Since capital mobility helps countries to reduce the constraint on their current accounts, they can specialize in the production of commodities where they have a relative factor advantage (Esteves, 2012). Another gain of capital mobility, particularly intensive in the decade 1880-1890 and in the decade before the world war, is a consequent reduction of Public Debt Service Yields spreads.

It is true, though, that the same era is dotted by episodes of financial turbulence. In South America one of the most remarkable episode is that of Argentina which drags the Baring bank. In Europe we have the relevant case of Portugal which defaults in 1892-1901. In Italy the discovery of illegal - non covered by gold - creation of monetary base by Banca Romana, one of the three Central banks of the country, does not imply sovereign default, but forces the country to exit from the CGS monetary regime. In spite of these relevant and others less important, but surely not negligible cases of sovereign debt crisis, the CGS era is featured by a decreasing number of country defaults in the years and by a widespread trust in the well functioning of the monetary system and the solvency of most of countries.

4. DATA AND EXPLORATORY ANALYSIS

The empirical exercise is based on the construction of a two-state annual transition matrix of countries switching from a ‘sound’ state to a ‘distressed’ state. Each transition matrix provides information on the percentage of countries in the sample that, from the t^{th} year to the $t+1^{th}$ year, have remained in their ‘beginning of period’ state, either ‘sound’ or in ‘distress’, or have moved to a different state ‘distressed’ or ‘sound’ respectively.

In order to construct and eventually study the properties of the transition matrices, we use a dataset drawn from Reinhart (2010). The dataset includes 42 countries. We construct a panel of countries that enter the sample only after their independence year.[6] In order to define external debt crises, which is the type of crisis we are interested in analysing, we consider Reinhart (2010) dataset, which provides the number of years in which a country experiences the missed or partial payment of coupons on Government bonds or debt restructuring, i.e. the change of the nominal value of the bonds into terms less favourable to the lender. In Appendix A and B we report the list of countries that we have considered. Before turning to the models we report some exploratory analysis.

4.1. *The percentage of default during the two eras*

Figure 1 reports for each year the percentage of countries in default in the CGS and in the IGES eras. We immediately notice that the percentage of default in both periods can be at times high and at times low, but in the IGES

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[6] We do not consider colonies, but we do consider dominions since they enjoyed some financial independence.

period after 1930 there is a break in the series. The difference between the two periods lies mainly in the variability. This is confirmed by the summary statistics reported in Table 1 where the variance of the percentage of distressed countries is much smaller in the former period compared to the latter. During the CGS period the lowest percentage of distressed countries is at the end of the temporal window and the highest at the beginning, for the IGES period (1925-1933) the lowest proportion of distressed is in 1926 and just a few years later, in 1932, it reaches its highest peak.

FIGURE 1. – *Percentage of countries in default*

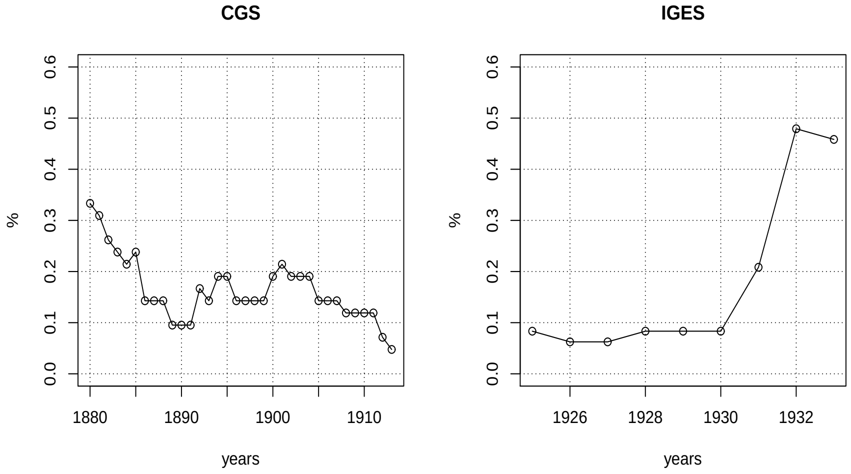

TABLE 1. – *Percentage of default countries summary statistics* [a]

		years	min	median	max	mean	st.dev.
1880-1913	CGS	34	4.8	14.3	33.3	16.4	6.3
1925-1933	IGES	9	6.3	8.3	47.9	17.8	17.1

[a] Statistics are referred to the CGS (Classical Gold Standard) era and the IGES (Interwar Gold Exchange Standard) era.

4.2. *The observed transition matrices*

We report in Table 2 some observed one year transition matrices in the two periods comparing the CGS era with the IGES era. From the visual inspection of the matrices it seems that the conditional distributions are characterized by a certain degree of stability in the CGS era and consequently by small changes in time (the elements of the transition matrices during the CGS era do not

Table 2. – *One-year observed transition matrices* [a]

CGS			**IGES**		
	1880-1881			**1925-1926**	
	sound	distressed		sound	distressed
sound	1.00	0	sound	1.00	0
distressed	0.07	0.93	distressed	0.25	0.75
	1885-1886			**1926-1927**	
	sound	distressed		sound	distressed
sound	1.00	0	sound	1.00	0
distressed	0.40	0.60	distressed	0	1.00
	1890-1891			**1927-1928**	
	sound	distressed		sound	distressed
sound	0.97	0.03	sound	0.98	0.02
distressed	0.25	0.75	distressed	0	1.00
	1895-1896			**1928-1929**	
	sound	distressed		sound	distressed
sound	1.00	0	sound	0.98	0.02
distressed	0.25	0.75	distressed	0.25	0.75
	1900-1901			**1929-1930**	
	sound	distressed		sound	distressed
sound	0.97	0.03	sound	1.00	0
distressed	0	1.00	distressed	0	1.00
	1905-1906			**1930-1931**	
	sound	distressed		sound	distressed
sound	0.97	0.03	sound	0.86	0.14
distressed	0.17	0.83	distressed	0	1.00
	1910-1911			**1931-1932**	
	sound	distressed		sound	distressed
sound	0.97	0.03	sound	0.66	0.34
distressed	0.20	0.80	distressed	0	1.00
	1912-1913			**1932-1933**	
	sound	distressed		sound	distressed
sound	1.00	0	sound	0.92	0.08
distressed	0.33	0.67	distressed	0.13	0.87

[a] The transition matrices are referred to the CGS era (left column) and the IGES era (right column).

change abruptly). In the IGES period small changes seem to take place up to 1930, but in the last three matrices the Table shows great movement between the different states. This comparison gives similar information as Figure 1, but from a different perspective. Another characteristic we would like to address in this exploratory section is whether the observed persistences, i.e. the observed yearly conditioned probabilities to remain sound (p_{00}) or distressed (p_{11}), present a trend (increasing or decreasing). In order to give some insight on this, we use a simple linear regression model in which the diagonal elements of the matrices proposed in Table 2 are expressed as a function of time: $p_{ii}=\hat{\alpha} + \hat{\beta}\cdot$t where i=0,1. Results are displayed in Table 3.

As we can see, in the CGS era, for both p_{00} and p_{11} the estimated trend $\hat{\beta}$ results to be significantly equal to 0. We cannot evaluate the statistical significance of the linear model applied to the IGES data, because of lack of information (only eight years). Nevertheless, the estimated trend coefficients are much higher than the corresponding ones in the CGS era (around one hundred times higher), signalling a more relevant trend during the IGES than the CGS.

The exploratory analysis of this section helps to grasp some features of the CGS era, which are the low variance of the percentage of defaults, the slow

TABLE 3. – *Linear Regression Results* [a]

	CGS era		IGES era	
	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\alpha}$	$\hat{\beta}$
p_{00}	0.98***	0.0002	1.02^{na}	-0.028^{na}
p_{11}	0.85***	-0.0005	0.88^{na}	0.0088^{na}

[a] We cannot report significance on the estimates for IGES (na=not available). H_0: $\beta = 0$. H_0 is **rejected** with significance level : '*' 0.1, '**' 0.05, '***' 0.01.

change in time of the unconditional distribution and the absence of a trend in the observed persistences. All these characteristics are not present in the IGES era. Even if interesting, the same analysis is only exploratory and does not make possible to draw trusty conclusions on the two eras.

In the next section we then verify whether the two time-homogeneous Markov models (MC and MS), which formally incorporate the characteristics found in the descriptive section, fit our data in the CGS era. If the stochastic process is Markov the hazard function is constant and the memory is short. From an economic point of view this implies the fast graduation of countries after suffering a default, which means quick and easy new access to the capital markets.

Time homogeneity, involved by the two models (MC and MS), implies the absence of trend of the conditional distributions, which confirms what emerges from comparing the one year transition matrices (see Table 2), and the convergence to an equilibrium distribution. From an economic point of view time homogeneity and the convergence to an equilibrium means a decreasing level of uncertainty for the markets during the CGS era. The fact that the rate of default decreases at the end of the CGS period (as shown in Figure 1) does not necessarily imply the existence of an equilibrium. The decisive aspect is not so much the final level of default rate, but how the process gets to it. A worse off equilibrium, guaranteed by the two Markov models, would also be fully consistent with time homogeneity.

5. THE MODELS

In this section we describe three stochastic processes we use to characterize the dynamics of countries during the CGS era. As in Frydman (1985), we choose to check if our data are suitably modelled by one among the classical Markov Chain (MC), the Mover Stayer model (MS), or the time-non-homogeneous Markov Chain (NHMC).

The aim of this procedure is to answer the following question: is the CGS period characterized by time-homogeneity, in terms of countries evolution between crisis/not crisis? Time homogeneity is a very relevant property because it causes a constant probability to become sound/distressed in the next year, when the state in the current year is known. As a consequence, we have that 1) the transition probabilities between crisis/not crisis do not show any recognizable trend and fluctuate around horizontal lines and 2) the unconditional probabilities change smoothly in time and in a predictable way converging towards the equilibrium distribution.

Formally speaking, let X_t^l be the random variable such that:

$$X_t^l = \begin{cases} 0 \text{ if the } l\text{-th country is sound at time } t \\ 1 \text{ if the } l\text{-th country is distressed at time } t \end{cases} .$$

The evolution of the l-th country with respect of time is represented by a sequence of 0 and 1 which is the realization of the discrete-time stochastic process $X_0^l, \ldots, X_T^l$, where X_0 and X_T are the usual notations for the starting and the last observed year (1880 and 1913 in our case). Omitting the country's label l, we say that:

Definition 1 *The stochastic process X_t satisfies the* time homogeneity *if*

$$P(X_{t+s}|X_t) = P(X_s|X_0)$$

for every $t, s \in \mathbb{N}$.

Definition 1 claims that if we consider, for example, the 1880 sound countries ($t = 0$) and the 1900 sound countries ($t = 10$), they have the same conditional probability to be distressed after five year ($s = 5$, respectively in 1885 and in 1905). If we set $s = 1$, then year-by-year transition probabilities are constant, as previously remarked, and they are given by $P(X_{t+1} = j|X_t = i) = P(X_1 = j|X_0 = i) = p_{ij}$.

Together with the time-homogeneity, is it also worth to recall the definition of Markov property:

Definition 2 *The stochastic process X_t satisfies the* Markov property *if*

$$P(X_{t+1}|X_t, \ldots, X_0) = P(X_{t+1}|X_t).$$

This property claims that only the knowledge about the state sound/not sound in the current year is needed to guess the state in the next year, whereas the previous path does not provide additional information. In other terms, if the countries evolution is characterized by the Markov property, then the probability to be sound or distressed in the next year is different for countries that are currently sound or currently distressed, whereas it does not depend, for example, on the state at time $t-1$ or on how many years the countries have suffered a crisis in the past. In this sense, the process is also said *memoryless*.

5.3. *Time-Homogeneous Markov Chain (MC)*

The most famous model satisfies both the time-homogeneity and the Markov property. The evolution of every country is supposed to be ruled by the transition matrix $P = \{p_{ij}\}_{i,j}$, defined as before.

Having P, we can also easily evaluate the s-steps transition probability

$$p_{ij}^{(s)} = Pr(X_{t+s} = j|X_t = i), \quad (1)$$

since $P^{(s)} = \left\{ p_{ij}^{(s)} \right\} = P^s$ (the s-th matrix-power of P). Note that time-homogeneity implies that $p_{ij}^{(s)} = Pr(X_{t+s} = j|X_t = i)$ is constant with respect to t, as explained before, that is the conditioned probability $Pr(X_{t+s} = j|X_t = i)$ depends only on the length s of the time window $[t, t+s]$.

If MC holds and the transition matrix is irreducible and ergodic (see Grimmet and Stirzaker, 1992), the same model admits an equilibrium distribution π which can be evaluated as follows:

$$\pi = p_0 \cdot lim_{t \to \infty} P^t, \tag{2}$$

where p_0 is the starting distribution with $p_{0i} = Pr(X_0 = i)$, for $i = 0, 1$.

5.3.1. *Additional properties of MC: Persistence time and Hazard function*

Persistence means the tendency to remain in the same state, which can be measured by the number of consecutive years across which a country is continuously sound or distressed. We consider the random variable Y describing the number of consecutive steps spent in the same state. If the MC holds, the persistence time for countries that are sound at time t is distributed according with the following probability distribution:

$$P(Y = k|X_t = 0) = P(X_{t+1} = \cdots = X_{t+k} = 0, X_{t+k+1} = 1|X_t = 0) =$$

$$= (p_{00})^k \cdot p_{01} = (1 - p_{01})^k \cdot p_{01},$$

for $k \in \mathbb{N}$. This is exactly the form of the geometric distribution with parameter $p = p_{01}$. Analogously, if we assume that $X_t = 1$, we obtain a geometric distribution with parameter $p = p_{10}$.
A related property regards the *hazard function*: generally speaking the hazard function, also called *hazard rate* or *force of mortality*, is the probability per unit of time that a country switches from sound to distressed (or vice versa) at time t, given that it has never switched before t. When the persistence time Y has a discrete distribution, as in our case, it is proved that the corresponding hazard function is given by $\lambda(t) = Pr(Y = t|Y > t - 1)$. In Xekalaki (1983) it is also proved that if Y has a geometric distribution with parameter p then the hazard function is constant and given by $\lambda(t) \equiv p$. Summarizing, the hazard function represents the *mortality* intended as the force which attracts countries out from their original state: if MC holds, such force is constant with respect of time, then the tendency to move from sound to distressed (or viceversa) does not increase (nor decrease) with the amount of time spent in the sound (distressed) state.

5.4. *Mover-Stayer model (MS)*

The MC model has the advantage to be easy to be estimated and equipped with many relevant properties, as shown before. Nevertheless it is based on the hypothesis that all the countries have the same identical evolution, because they are supposed to evolve according to the same transition matrix P. This strong assumption may provide a not-realistic representation of the dynamics under study. The MS model, proposed for the first time by Blumen et al. (1955), is instead based on a weaker hypothesis, since countries are supposed to be subdivided in two groups, the *Movers* and the *Stayers*. The former group is ruled by a classical Markov chain with transition matrix M, whereas the latter contains individuals never moving from their starting state, and then following a degenerate chain with transition matrix equal to the identity I. The relevant advantage of MS is its possibility to model countries heterogeneity, since their behaviour depends on the group they belong to (in any case, it is worth noting that individuals in the same group have the same behaviour).

Let s_i be the probability of being a Stayer in state $i = 0, 1$, and let S be the diagonal matrix $diag\{s_0, s_1\}$, then the global transition matrix is given by

$$P = S + (I - S) \cdot M, \tag{3}$$

where I is the identity matrix. In MS the Markov property and time-homogeneity still hold, but the transition probabilities have the following form:

$$p_{ij} = \delta_{ij} \cdot s_i + (1 - s_i) \cdot m_{ij}, \tag{4}$$

where δ_{ij} is the Kronoecker Delta, equal to 1 if $i = j$, 0 otherwise, $i, j = 0, 1$. As a consequence, the transition matrix after s steps is no longer equal to a power of P as before, but it is given by the following rule:

$$P^{(s)} = S + (I - S) \cdot M^{(s)} \neq P^s. \tag{5}$$

If MS holds and the matrix M is irreducible and ergodic, the equilibrium distribution exists and it can be calculated similarly to the MC model:

$$\pi = p_0 \cdot lim_{t\to\infty} P^t = p_0 \cdot \left[S + (I - S) \cdot lim_{t\to\infty} M^t\right]. \tag{6}$$

Lastly, it is noticeable that the MS is analogous to MC in terms of persistence time and hazard function. Indeed, we can prove that the persistence time for the Movers (Stayers obviously have infinite persistence time) is distributed as a geometric distribution with parameter $p = (1 - s_0) \cdot m_{01}$ for countries remaining for k years in the sound state, and $p = (1 - s_1) \cdot m_{10}$ for countries in the distressed state.

5.5. *Time-Non-Homogeneous Markov Chain (NHMC)*

In this model the time-homogeneity assumption is discarded, which implies that the system does not converge to an equilibrium distribution and that the hazard function is not constant. The transition matrix is a function of time and for every value of t we have transition probabilities defined as

$$p_{ij}(t) = Pr(X_{t+1} = j | X_t = i), \tag{7}$$

and a transition matrix $P(t) = \{p_{ij}(t)\}$, such that $P(t) \neq P(s)$ if $t \neq s$. It is worth noting that, since conditional probabilities depend on t in an unknown way, we can not forecast the probability to be sound or distressed in the future years, and the equilibrium distribution generally does not exist (except for the particular case in which $p_{ij}(t)$ can be described by a function with horizontal asymptote).

5.6. *Alternative and long-memory models*

Many alternative and more complicated models have been proposed in the literature, to better describe the reality. For example, spatial homogeneity has been sometimes discarded in favour of models considering two or more subgroups moving with different speeds (Frydman and Shuermann, 2008), or time-non-homogeneous mixtures of movers and stayers (Frydman and Kadam, 2004). On the other hand, a relevant role is played by models which suppose a longer memory than the MC. The stochastic process X_t is said to be a *Markov Chain of order* r if it holds

$$P(X_{t+1}|X_t, \dots, X_0) = P(X_{t+1}|X_t, \dots, X_{t-r}),$$

(see among others Zhao et al., 2001). It means that the next step does not depend on the whole history but on the path followed in the r previous steps. Note that such models are very close to the autoregressive models AR(r). X_t may be time- or spatially homogeneous as before, but the main issue about this model is that the number of parameters to be estimated grows exponentially with r (e.g. if $r = 2$ we must consider all the k^3 possible triplets of consecutive states).

6. ESTIMATION AND BOOTSTRAPING HYPOTHESIS TESTING

As explained in the previous section, our aim is to establish which properties are characterizing the evolution of countries during the CGS era. If MC (or MS) fits the data, we can say that countries display a time homogeneous behaviour, that their evolution is regular with respect to time and the system tends to an equilibrium. In choosing the models to be compared, we have to deal with the problem of data scarcity. We have indeed only 42 countries and we cannot perform a test about higher ordered MCs as in Anderson and Goodman, 1957, p. 99, because of the presence of many empty cells. We then lean towards a 'forward' approach in which we start with the simplest models (MC and MS), possibly adding some modification if they should fail to fit the data.

We organize the analysis in the following steps:

1. We estimate the parameters of MC, MS and NHMC through the Maximum Likelihood estimator, as proposed in Anderson and Goodman (1957) and in Frydman et al. (1985).
2. To attest the presence of time-homogeneity, Frydman et al. (1985) suggest

to apply a Likelihood Ratio test for choosing between MC and NHMC.[7] To avoid drawbacks related to the small sample size, we use a bootstrapped version of such test as in MacKinnon (2009), as it will be explained in the following Section.

3. Having ascertained time-homogeneity, we use MC or MS to obtain the best fit. To choose between them, an analogous Likelihood Ratio test exists, but, as pointed out in Frydman and Kadam, 2004, p. 164, 'result may not be valid ... because the null hypothesis specifies the boundary value of' the probability to be a Stayer. Consequently, we firstly apply a bootstrapped goodness-of-fit test to check if the models suitably fit with our data, and then we try to choose the best model according to the *Hellinger distance*. Such a distance is used to properly measure the degree of similarity between two probability distributions, both continuous or discrete. In the case of two discrete distributions p and q having the same k possible outcomes, it is defined by:

$$H(p,q) = \frac{1}{\sqrt{2}}\sqrt{\sum_i \left[\sqrt{p(i)} - \sqrt{q(i)}\right]^2},$$

   where $p(i)$ and $q(i)$ are the probabilities associated to the outcome i, $i = 1, \ldots, k$ (for more details, see Cipollini et al., 2012). In particular, we compare, for every year, the Hellinger distance between the observed yearly distribution of sound/distressed countries p_t^{obs} with the corresponding estimated p_t^{est} provided by MC and MS. Ideally, the best model is associated to the lower distance from p_t^{obs}.

6.7. *Bootstrapping and Bootstrap Hypothesis testing*

As mentioned before, the small sample size at our disposal creates several problems. In particular, we cannot consider valid the asymptotic results about the standard tests of hypothesis. Consider for example the Log-Likelihood ratio test which should be used to compare MC with NHMC (note again that MC is a special case of NHMC). The null hypothesis is H0: 'the nested model MC holds' against H1: 'the alternative model NHMC holds'. The corresponding test statistic D is related with the ratio of the loglikelihood function under H0 with the same function evaluated under H1 and it is asymptotically Chi-squared-distributed. Bootstrap tests of hypothesis have the role of avoiding parametric assumptions which are not founded when the sample is too small. In this case, as explained in Hall and Wilson (1991) and in MacKinnon (2009), we bootstrap B fictitious samples under the hypothesis H0, and for every $b = 1, \ldots, B$ we

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[7] To our knowledge a test that compares NHMC to MS does not exist. The likelihood-ratio test generally compares two models in which one can be seen as a special case of the other one. Since MS is not a special subset of NHMC, we consider MC as a special case of NHMC to test time-homogeneity.

calculate the corresponding test statistics D_b. The so-called *bootstrapped p-value* corresponds to the percentage of D_b values which are higher than the original observed statistic D.

The same technique holds for applying a non-parametric goodness-of-fit test. Consider for example the MC model: for every year H0 claims that the observed distribution p_t^{obs} is a realization of the expected distribution p_t^{est}. Under H0, the test statistic is

$$C = n \cdot \sum_i \frac{(p_t^{obs}(i) - p_t^{est}(i))^2}{p_t^{stim}(i)}$$

is asymptotically chi-squared-distributed, again. We then bootstrap B samples under the hypothesis H0 and we evaluate

$$C_b = n \cdot \sum_i \frac{(p_{t,b}t^{obs}(i) - p_{t,b}^{est}(i))^2}{p_{t,b}^{est}(i)}$$

Where $p_{t,b}t^{obs}$ and $p_{t,b}t^{est}$ are the observed and estimated distributions in every fictitious sample. The bootstrapped p-value is the percentage of C_b which are higher than C.

7. RESULTS

The statistical test reported in Table 4 confirms that the MC fits the data during the CGS era. In order to better grasp the relevance of our estimates we also run the same exercise in the Interwar period, i.e. during the second and last GS era. Differently from what happens during the CGS in the second period NHMC clearly beats MC.

TABLE 4. – *Bootstrap hypothesis test: MC versus NHMC* [a]

Period	Era	Observed test statistic	Bootstrapped p-value
1880-1913	CGS	89.69	0.0251*
1925-1933	IGES	56.49	0.0000

[a] H_0: MC fits the data (H_a: NHMC fits the data). H_0 is not rejected with significance level : '***' 0.1, '**' 0.05, '*' 0.01.

In order to check the goodness of fit of MC and MS we show in Table 5 that both models are not rejected by the bootstrapped goodness-of-fit test. In this light, we find support for the hypothesis that time-homogeneity and the Markov property are adequate assumptions for describing the dynamics between sound and distressed during the CGS era. The fact that MC and MS (time-homogeneous Markov Models) fit the observed transition matrices well, imply three different properties. The first is that the conditional probabilities are stable in time consistently with what we have eye-balled empirically in Table 2 of the explanatory section. The second it that the unconditional probabilities, i.e. the probability to be sound or distressed after a fixed time length

Table 5. – *Goodness-of-fit test for MC and MS* [a]

	1881	1882	1883	1884	1885	1886
MC	0.848***	0.956***	0.973***	0.933***	0.513***	0.416***
MS	0.765***	0.491***	0.425***	0.429***	0.211***	0.715***
	1887	1888	1889	1890	1891	1892
MC	0.538***	0.657***	0.210***	0.247***	0.289***	0.552***
MS	0.652***	0.596***	0.930***	0.915***	0.907***	0.278***
	1893	1894	1895	1896	1897	1898
MC	0.876***	0.184***	0.165***	0.722***	0.691***	0.674***
MS	0.435***	0.125***	0.119***	0.395***	0.386***	0.376***
	1899	1900	1901	1902	1903	1904
MC	0.651***	0.104***	0.025*	0.093**	0.089**	0.086**
MS	0.369***	0.107***	0.051**	0.104***	0.101***	0.105***
	1905	1906	1907	1908	1909	1910
MC	0.574***	0.566***	0.565***	0.978***	0.972***	0.969***
MS	0.356***	0.355***	0.361***	0.597***	0.597***	0.601***
	1911	1912	1913			
MC	0.964***	0.272***	0.093**			
MS	0.596***	0.828***	0.556***			

[a] The table reports the bootstrapped p-value. H_0: the statistical model (MC or MS) fits the data. H_0 is not rejected with significance level : '***' 0.1, '**' 0.05, '*' 0.01.

independently from the starting state, changes in time with decreasing intensity until the equilibrium distribution is reached.[8] Given that MC and MS models fit the observed transition matrices well during the CGS era, we are able to forecast the (unconditional) probability of being sound or distressed after 1, 2, 10, 20, 50 years from the starting period until the steady state (equilibrium) is reached. This means that if the conditions of the CGS era would have remained unchanged also after 1913, the probability of being sound or distressed would have reached a steady state and the models are also able to quantify the probability forecasts of being sound or distressed in the same steady state. The third property, guaranteed by MC and MS during the CGS era, is a constant hazard function, i.e. the probability of default does not depend on the amount of years spent in a sound state since the last default. Differently from the CGS, the IGES period, is not governed by time-homogeneity and thus all the properties described do not apply in this period of time.

Table 6 shows the unconditional probabilities of being sound (distressed), implied by MC and MS, estimated during the CGS era. The Table shows that the model-implied proportion of sound and distressed during the CGS era is not

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[8] The existence of the equilibrium distribution is assured by the irreducibility of the estimated one-year matrix (which in other words means that it is possible to go from any state to any state) and by its ergodicity (for details see Grimmet and Stirzaker, 1992). In any case we can easily verify that the one-year matrix satisfies the statements of the Perron-Froboenius theorem, i.e. it is irreducible and it has only one eigenvalue equal to one. As a consequence the equilibrium distribution exists and is unique.

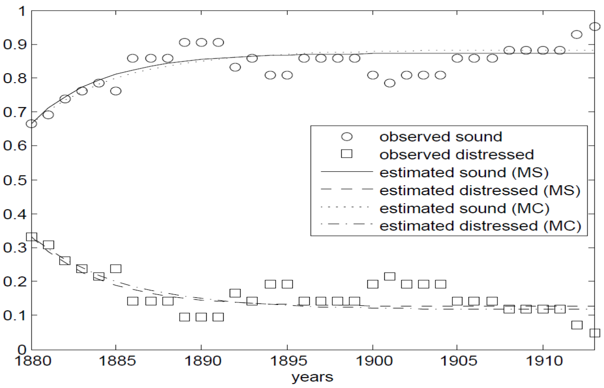
constant, but changes in time with decreasing intensity until the equilibrium distribution is reached. The steady state would be reached within 50 years with 88.3% of sound countries and 11.7% of distressed if we consider the MC model, and with 87.3% of sound countries and 12.7% of distressed if we consider the MS model. Figure 2 shows graphically the theoretical and observed transitions from sound to crisis states. Also from this Figure we can see that both models are very close to the observed data.

TABLE 6. – *Estimated unconditional probabilities forecasts and equilibrium* [a]

					MC			
horizon	1	2	3	4	5	10	20	eq.=50
sound	70.37%	73.43%	75.98%	78.09%	79.84%	85.00%	87.82%	88.33%
distressed	29.63%	26.57%	24.02%	21.91%	20.16%	15.00%	12.18%	11.67%
					MS			
horizon	1	2	3	4	5	10	20	eq.=50
sound	71.09%	74.56%	77.29%	79.43%	81.12%	85.45%	87.14%	87.31%
distressed	28.91%	25.44%	22.71%	20.57%	18.88%	14.55%	12.86%	12.69%

[a] The forecast horizon (horizon) is expressed in years. The equilibrium (eq.) is reached after 50 years. MC and MS models are estimated over the CGS era (1880-1913).

FIGURE 2. – *Estimated and observed unconditional probabilities (MC and MS)*



The last question regards the choice of the model (MC versus MS) which better fits our data. On one hand we feel that the MS model represents a more realistic choice given the presence of many countries in our sample which never move from the sound state (i.e. the core countries that never default during the period); on the other hand the percentage of countries never moving from the distressed state (only Honduras) is near zero, affecting the estimation of the parameters of the MS model and its prevalence in fitting the data. Table 7 contains the Hellinger distance between the observed distribution and the corresponding estimated one for both MC and MS. In particular, to avoid sample-related anomalies and by analogy with the bootstrapped goodness-of-fit test , we bootstrap B=9999 fictitious samples under MC (or MS) and we calculate the distance H_b, $b = 1, \dots, B$. Table 7 then contains the mean distance and the related standard error. We see that under the MC model, the mean Hellinger distance between the distribution $p^{est}_{t,b}$ and the corresponding sample distribution $p_{t,b}$ is often higher than the distance obtained when we repeat the exercise under the MS model, even if we can notice that they have quite similar values. Then, as expected, results are not neatly in favour of MC or MS, and we are not able to discriminate which of the two homogeneous models is better in fitting the data.

Table 7. – *Mean Hellinger Distance* [a]

	1881	1882	1883	1884	1885	1886	1887
MC	0.0444	0.0433	0.0437	0.0437	0.0518	0.0548	0.0491
se	(0.0351)	(0.0341)	(0.0348)	(0.0346)	(0.0405)	(0.0401)	(0.0373)
MS	0.0457	0.0444	0.0448	0.0443	0.0578	0.0503	0.0474
se	(0.0361)	(0.0351)	(0.0356)	(0.0354)	(0.0440)	(0.0383)	(0.0366)
	1888	1889	1890	1891	1892	1893	1894
MC	0.0462	0.0701	0.0652	0.0616	0.0503	0.0448	0.0676
se	(0.0364)	(0.0455)	(0.0443)	(0.0431)	(0.0404)	(0.0368)	(0.0488)
MS	0.0453	0.0662	0.0626	0.0600	0.0505	0.0451	0.0662
se	(0.0355)	(0.0446)	(0.0433)	(0.0423)	(0.0404)	(0.0370)	(0.0476)
	1895	1896	1897	1898	1899	1900	1901
MC	0.0702	0.0476	0.0481	0.0486	0.0486	0.0775	0.0969
se	(0.0491)	(0.0394)	(0.0398)	(0.0400)	(0.0400)	(0.0513)	(0.0551)
MS	0.0679	0.0457	0.0459	0.0463	0.0458	0.0705	0.0878
se	(0.0486)	(0.0378)	(0.0380)	(0.0388)	(0.0390)	(0.0496)	(0.0536)
Year	1902	1903	1904	1905	1906	1907	1908
MC	0.0790	0.080	0.080	0.0511	0.0510	0.0510	0.0449
se	(0.0527)	(0.0529)	(0.0526)	(0.0419)	(0.0424)	(0.0421)	(0.0373)
MS	0.0709	0.0716	0.0724	0.0476	0.0475	0.0476	0.0449
se	(0.0498)	(0.0503)	(0.0506)	(0.0398)	(0.0397)	(0.0402)	(0.0370)
	1909	1910	1911	1912	1913		
MC	0.0454	0.0449	0.0449	0.0621	0.0897		
se	(0.0375)	(0.0378)	(0.0377)	(0.0438)	(0.0506)		
MS	0.0447	0.0443	0.0444	0.0702	0.0996		
se	(0.0372)	(0.0371)	(0.0365)	(0.0457)	(0.0520)		

[a] The table reports the bootstrapped mean distance between observed and simulated distributions for MC and MS. Results are referred to the CGS period (1880-1913). Standard errors (se) are reported in parenthesis.

To conclude, the hypothesis tests we propose in this section support the economic idea that the CGS era was characterized by an appreciable regularity with respect to time. Time-homogeneity is indeed not rejected by the corresponding statistical test, and both MC and MS, which are theoretically equipped with such property together with the Markov property, seem to be able to suitably fit our data. Such statistical regularity, which describes the CGS era (and not the IGES), is important to explain from an historical perspective sovereign debt markets in the two periods.

In the first period sovereign debt markets are predictable. The history of default of a country is not relevant for the markets, the graduation from default for countries is easy, the conditions regarding default are stable and the economic system converges towards an equilibrium in which the unconditional probability of default becomes progressively lower as time goes by. The second period is instead governed by uncertainty.

Our paper relates to the empirical question on how creditors react towards default countries. The fact that in the CGS era sovereign debt markets have short memory and the system is characterized by a rising degree of trust, which enables an easy access to capital markets, implies that the creditor's punishment, seen as the exclusion from the access to future lines of credit, is not in place. Countries are able to graduate from default relatively quickly.

Our results are consistent with those of Lindert and Morton (1989), which differently from this paper, look at the absence of punitive interest rates charged to countries with a poor record of debt repayment. Özler (1993), similarly to our paper, compares default episodes in the 1820-1829 period to those after 1930s and shows that only defaults prior to the 1930s do not have any impact on credit terms.

Our results are in contrast to those of Reinhart and Rogoff (2009) and that part of the literature which, looking at long spans of time, emphasizes the presence of serial defaulters, typically associated with a vicious circle of default which ends up in a spiral of debt, and their difficulty in graduating to a better state.

In comparison with the existent literature on the issue, we feel that our paper contributes in giving a more sophisticated analysis of the CGS era, by not focusing on interest rates, but studying the transition process of switching from one state to the other through the light of three stochastic models that incorporate some precise features that have important historical implications. Other than the Markov property and the constant hazard function, the models are able to say something also on the level of certainty/uncertainty present in the two periods, comparing the conditional probabilities from one year to the other and being able to tell whether the system converges to an equilibrium.

8. CONCLUSIONS

In this paper, through the use of three stochastic models, we study sovereign debt default during the CGS era. Because MC and MS, fit the CGS era we are allowed to draw some important conclusions on sovereign debt markets during this period.

The first, made possible by the Markov property of this model and the constancy of the hazard function is the irrelevance of history for the probability of default. Only the recent past has an impact on the same probability. It is evident that this conclusion is consistent with that of Lindert and Morton (1989) and Özler (1993) which find the absence of punitive interest rates charged to countries with a poor record of debt repayment.

The second conclusion, which emerges by the fitting of MC and MS, is the low degree of uncertainty that characterizes the sovereign debt market during the CGS era. These two stochastic models show in fact the tendency of the world economy to an equilibrium distribution in which the probability of default is much lower. IGES era is not fitted by MC and MS, but by NHMC. Differently from the first two models, this third model is not characterized by a constant hazard function. The irrelevance of past history can no longer be confirmed. This last conclusion seems to be consistent with the results of Özler (1993), which shows that defaulters of the post-WWII period are charged rates significantly higher than non-defaulters.

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TABLE 8. – *Appendix A. Adherence and Default years during the CGS* [a]

countries	CGS dates [b]	Default dates [c]
Argentina	1867-1876;1883-1885;1900-1914	1890-1893
Australia	1852-1915	-
Austria-Hungary	1892-1914	-
Belgium	1878-1914	-
Bolivia	1908-1914	-
Brazil	1888-1889;1906-1914	1898-1901
Bulgaria	1906-1914	-
Canada	1854-1914	-
Chile	1895-1898	1880-1883
China	-	-
Colombia	-	1880-1896;1900-1904
Costa Rica	1896-1914	1874-1885;1895-1897;1901-1911
Denmark	1872-1914	-
Dominican Republic	1901-1914	1872-1888;1892-1893;1897;1899-1907
Ecuador	1898-1914	1868-1890;1894-1898;1900-1904;1906-1911
Egypt	1885-1914	1876-1880
El Salvador	-	1898
France	1878-1914	-
Germany	1871-1914	-
Greece	1885;1910-1914	1894-1897
Guatemala	-	1876-1888;1894;1899-1913
Honduras	-	1873-1925
Italy	1884-1893; ***1894-1913***	-
Japan	1897-1917	-
Mexico	1905-1913	1866-1885
Netherlands	1875-1914	-
Nicaragua	-	1894-1895;1911-1912
Norway	1875-1914	-
Paraguay	-	1874-1885;1892-1895
Peru	1901-1914	1876-1889
Portugal	1854-1891; ***1895-1914***	1892-1901
Romania	1890-1914	-
Russia	1897-1914	1885
Spain	***1900-1914***	1877-1882
Sweden	1873-1914	-
Switzerland	1878-1914	-
Thailand	-	-
Turkey	1881-1914	1876-1881
UK	1821-1914	-
Uruguay	1876-1914	1891
US	1879-1917	-
Venezuela	-	1865-1881;1892;1898-1905

[a] World Independent countries in the CGS period (1880-1913). Shadowing periods in ***italics*** following Bordo and Rockoff (1996), Martín-Aceña (1994), Reis (1996) and Tattara (2003).

[b] according to Officer (2010).

[c] according to Reinhart (2010).

TABLE 9. – *Appendix B. Adherence and Default years during the IGES* [a]

countries	Interwar GES dates [b]	Default dates [c]
Argentina	1927-1929	-
Australia	1925-1929	1932
Austria	1923-1931	1932-1933
Belgium	1925-1935	-
Bolivia	1928-1931	1931-1948
Brazil	1927-1930	1931-1933
Bulgaria	1927-1931	1932
Canada	1926-1931	-
Chile	1926-1932	1931-1947
China	-	1921-1936
Colombia	1923-1931	1932-1934
Costa Rica	1922-1932	1932-1952
Denmark	1927-1931	-
Dominican Republic	1919-1933	1931-1934
Ecuador	1927-1932	1929-1954
Egypt	1925-1931	-
El Salvador	1920-1931	1932-1935
Finland	1926-1931	-
France	1928-1936	-
Germany	1924-1931	1932-1953
Greece	1928-1931	1932-1964
Guatemala	1924-1933	1933-1936
Honduras	1931-1934	1925
Hungary	1925-1931	1932-1933
Italy	1927-1936	-
Japan	1930-1931	-
Mexico	1925-1931	1928-1942
Netherlands	1925-1936	-
New Zealand	1929-1931	-
Nicaragua	1919-1931	1932-1937
Norway	1928-1931	-
Panama	1919-1933	1932-1946
Paraguay	1927-1929	1932-1944
Peru	1931-1932	1931-1951
Poland	1927-1936	-
Portugal	1929-1931	-
Romania	1929-1932	1933-1958
South Africa	1925-1932	-
Spain	-	-
Sweden	1924-1931	-
Switzerland	1925-1936	-
Thailand	-	-
Turkey	-	1915-1928; 1931-1932
United Kingdom	1925-1931	-
United States	1919-1933	-
Uruguay	1928-1932	1932-1938
URSS	-	1918-
Venezuela	1927-1930	-

[a] World Independent countries in the IGES period (1925-1933).

[b] according to Kemmerer (1954).

[c] according to Reinhart (2010).