NBER WORKING PAPER SERIES

HOW MANY MONIES? A GENETIC APPROACH TO FINDING OPTIMUM CURRENCY AREAS

Atish R. Ghosh
Holger C. Wolf

Working Paper No. 4805

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 1994

This paper is part of NBER's research program in International Finance and Macroeconomics. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

NBER Working Paper #4805
July 1994

HOW MANY MONIES? A GENETIC APPROACH TO FINDING OPTIMUM CURRENCY AREAS

ABSTRACT

Recent moves towards greater monetary integration in Western Europe - and disintegration in Eastern Europe and the former Soviet Union - have rekindled interest in the theoretical and empirical aspects of optimal currency areas (OCA). In this paper, we examine the marginal benefit of increasing the number of currency unions within a given geographical area. We look at six regions; the United States, Europe, the G7, the CFA zone, the FSU and the world at large. Our results suggest that (i) contiguous monetary unions are typically dominated by non-contiguous unions; (ii) neither Europe nor the United States form an optimum currency area, for both regions the costs of adopting a single currency exceeds estimates of the transaction cost savings; (iii) Germany and the United States will almost never find it to their (economic) advantage to join monetary unions.

Atish R. Ghosh
Woodrow Wilson School
Princeton University
Princeton, NJ 08544

Holger C. Wolf
Stern Business School
New York University
44 West 4th Street, MEC 7-78
New York, NY 10012
and NBER

1 Introduction

Recent moves towards greater monetary integration in Western Europe — and disintegration in Eastern Europe and the Former Soviet Union — have rekindled interest in the theoretical[1] and empirical[2] aspects of optimal currency areas (OCA).[3] Much of the new empirical literature applies the criteria developed by Mundell (1961), McKinnon (1963), and Kenen (1969) to compare a candidate region to an existing monetary union, the most fashionable example being the comparison between the EMS countries and the US states, where the Maastricht signatories are typically judged to be an inferior candidate for a monetary union compared to the US states. While interesting in their own right, these studies are, by construction, restricted to accepting or rejecting the proposition that a given region constitutes a "better" candidate for a single currency than the chosen benchmark currency area. There is however no reason to believe that for a region with n countries the optimal monetary arrangement will be either a single currency or n independent currencies. Among the twelve European Union countries, for instance, the optimal configuration may involve two, or three, currencies rather than either one or twelve.

To allow for this possibility, we adopt a more continuous approach towards determining OCAs in this paper. Based on an evaluation principle developed below, we determine the optimal grouping of n countries into any *given* number of monetary unions k, with k ranging from 1 to n. We then relate macroeconomic performance to the number of unions, thus deriving an estimate of the *marginal* contribution of an additional currency. The approach yields two insights. First, we are able to determine optimal membership patterns for any given number of monetary unions. Second, we are able to determine — for any given country group — how many monies are needed to capture most of the benefits of exchange rate flexibility.

We address these questions for a variety of country groupings. We begin with the United States — long suspected not to be an optimal currency area [Mundell (1961)]. While the abandonment of the common dollar scarcely seems imminent, the case allows identification of state groups subject to similar shocks and permits a comparison with the regional struc-

[1] See for example Casella (1990), Melitz (1991), Aizenman and Flood (1993) and Bayoumi (1994).

[2] See for example Goodhart (1993) and the papers in Masson and Taylor (1993), along other work cited below.

[3] For a description of historical experiences with monetary unions, see Graboyes (1990).

ture of the Federal Reserve System. Next, we turn to a group of twenty European countries, evaluating the relative merits of various monetary unions, and comparing them to the EMS grouping. Third, we review recent proposals for greater stability of the exchange rates among the G-7 countries.[4] We interpret such proposals in an extreme form, and consider the costs (in terms of foregone opportunities for macroeconomic stabilization) of adopting common currencies for the G-7. Our fourth and fifth cases are the states of the Former Soviet Union, and the CFA countries. Finally, we turn to the world at large.

Answering the first question — the optimal groupings of countries for a given number of monetary unions — is rather non-trivial: given current computing facilities, the number of possible permutations of n countries into k groups of various sizes rules out a brute force computation of the optimal arrangement. We instead use a variant of the *genetic algorithm* optimization approach to compute the optimal groupings, and then vary the total number of currency unions to find the marginal benefit of an additional currency.

Our general conclusions may be summarized briefly. First, there is typically little correlation between geographical proximity and the optimal currency area groupings. Put differently, restricting monetary unions to geographically contiguous areas implies significantly higher costs from foregoing the use of the exchange rate as an adjustment instrument. Second, for most regions we consider, adopting a *single* currency would appear to entail prohibitively high costs. For instance, in the case of the US States, the cost of maintaining a single currency (ignoring the transactions benefits) amounts to some 2.5 percent of US GDP per year - almost 150 billion current US $. The corresponding figures for the European countries, and for the Group of Seven major industrialized nations, are very similar, at around 2.6 percent of their respective GDPs. These are well in excess of transactions costs benefits, as estimated by the European Commission, of 0.5 percent of GDP per year. On the other hand, most of the stabilization benefits of independent currencies can be captured by having relatively few currencies. With five currencies among the fifty US states, and three currencies among the twelve European Union countries, the stabilization costs fall to less than 1.5 percent of GDP. For the other regions we consider, the CFA countries, the States of the Former Soviet Union, and the world at large, the costs of adopting a single currency are significantly higher.

[4]See, for example, the Report of the Bretton Woods Commission (1994).

The remainder of this paper is organized as follows. Section 2 briefly reviews the theory of optimal currency areas, and develops the theoretical framework for our empirical work. Since the use of genetic algorithms is still quite rare in economics, section 3 provides an overview of how such algorithms work. Section 4 reports the main empirical results for our six data sets and section 5 concludes.

2 The Theory Of Optimal Currency Areas

The nominal exchange rate regime will only have real economic effects in the presence of some form of nominal rigidity. If, as is typically assumed, nominal wages are downward sticky, then changes in the price level will elicit a corresponding change in the real wage, and can bring the economy closer to full employment following an adverse productivity shock, or — in a world with multiple goods — a change in the demand for that country's output. To the extent that shocks impinge upon countries asymmetrically, however, the desired changes in the price level will differ across countries, and the nominal exchange rate will need to adjust. Adopting a common currency (or, equivalently, an irrevocably fixed exchange rate) thus limits the stabilization scope of monetary policy to shocks that are symmetric to the countries in the monetary union.

A simple macroeconomic model can be used to sketch this idea. It bears emphasizing, however, that the main results hold very generally, and few of the specific assumptions — except for the nominal wage rigidity — are required. Let output in country i at time t be given by:

$$Q_t^i = e^{\theta_t^i} L_t^{\beta} \tag{1}$$

where θ_t^i is a random shock, L_t is labor employed in period t, and $0 < \beta < 1$ is the share of labor. Nominal wages are downward sticky [5]. A simple formulation is to assume that the (log) of the nominal wage is set in order to obtain labor market equilibrium based on information available in period $t-1$:

[5] Alternatively, one can assume that nominal wages are pre-determined (and thus both upward and downward sticky). Such a model gives very similar results if the monetary authorities are assumed to want to minimize the variance of output.

$$\log(w_t^i) - E_{t-1}\log(p_t^i) = E_{t-1}\theta_t^i + (\beta - 1)\log(\bar{l}) \tag{2}$$

Since wages are downward sticky, the *ex post* level of labor demand depends on whether the realized productivity shock was lower than expected. If there was a positive productivity shock, $\theta^i > E_{t-1}\theta^i$, nominal wages are assumed to adjust, and full-employment prevails. In the face of a negative productivity shock, however, nominal wages are rigid so that *ex post* labor demand l_t^i is given by:

$$\theta_t^i + (\beta - 1)\log(l_t^i) = \log(w_t^i) - \log(p_t^i) = E_{t-1}\theta_t^i + (\beta - 1)\log(\bar{l}) - \log(p_t^i) \tag{3}$$

If the country is *not* in a monetary union, the monetary authorities can alter the price level in order to cut real wages following a negative productivity shock, $\theta_t^i - E_{t-1}\theta_t^i < 0$, in order to emulate the flexible nominal wages:

$$\log(p_t^i) - E_{t-1}\log(p_t^i) = E_{t-1}\theta_t^i - \theta_t^i \equiv -\varepsilon_t^i \tag{4}$$

so that full-employment always prevails, $l_t^i = \bar{l}$, and:

$$Q_t^i = e^{\theta_t^i}\bar{L}^\beta \tag{5}$$

The change in the domestic price level will be associated with a change in the nominal exchange rate, unless the foreign country experiences the same shock. For instance, if two countries, i and j, produce the same good, then purchasing power parity should hold:

$$\begin{aligned} \log(e_t) - E_{t-1}\log(e_t) &= [\log(p_t^i) - E_{t-1}\log(p_t^i)] - [\log(p_t^j) - E_{t-1}\log(p_t^j)] \\ &= -(\varepsilon_t^i - \varepsilon_t^j) \end{aligned} \tag{6}$$

and country i's exchange rate will need to depreciate when it suffers a larger negative shock to its output than does country j. It bears emphasizing that the assumption of PPP is not essential; a model with multiple goods and real exchange dynamics will give very similar results (see for example Bayoumi (1994)).

Suppose, instead, that the two countries have formed a monetary union, so that the nominal exchange rate must be constant. If the average shock to the members of the union

in period t is $\bar{\varepsilon}_t$, then $\log(p_t^i) = \log(p_t^j) = -\bar{\varepsilon}_t$, so that the *ex-post* labor demand is given by:[6]

$$l_t^i/\bar{l} = e^{(\varepsilon_t^i - \bar{\varepsilon}_t)/(1-\beta)} \tag{7}$$

and output, when the country belongs to the union, $\hat{Q}$, is given by:

$$\hat{Q}_t^i/Q_t^i = e^{(\varepsilon_t^i - \bar{\varepsilon}_t)/(1-\beta)} \tag{8}$$

Therefore, when $(\varepsilon_t^i - \bar{\varepsilon}_t) < 0$, country, i, suffers an output loss equal to:

$$L^i = [1 - e^{(\varepsilon_t^i - \bar{\varepsilon}_t^i)/(1-\beta)}]Q_t^i \;\; if \varepsilon_t^i < \bar{\varepsilon}_t^i \tag{9}$$

where $\bar{\varepsilon}_t^i$ is the average shock to the currency union to which country i belongs. For a region with n countries, one possible welfare function is the total cost of forming currency unions:

$$L = \sum_{i=1}^{n} L^i \tag{10}$$

While the welfare function (10) is certainly reasonable, it is noteworthy that it has the property of treating a "dollar" in each country equally, regardless of the per capita GDP of that country. In effect, this means that when there relatively few independent currencies, larger countries should be allocated their own currency while smaller countries share a common currency. The reason is simple: when a large country suffers a negative shock the cost, in terms of foregone output, of not allowing the exchange rate to adjust will be very high. From a global perspective, therefore, such countries should maintain an independent monetary policy. Smaller countries, in contrast, can share a common currency because, even though their shocks may be large relative to their own GDP, the total output cost from a global perspective may be quite modest.

The model is obviously highly simplified, but it provides a basis for an empirical assessment of the cost of adopting common currencies, and for identifying which countries would be the optimal partners in a region with (parametrically given) n countries and k

[6]Generalizing to currency unions with n members is straight-forward. In our empirical work, we use the GDP weighted average of the shock. Thus monetary policy in the union is assumed to be determined by a GDP-weighted average of the desired policies of the members.

currencies. The optimal country groups are likely to be quite robust to changes in the specification of the model since they depend only upon the commonality of shocks to the monetary union. The extent to which the actual costs associated with the limitation will coincide with the model's predictions depends upon five factors.

First, rigidity of the nominal exchange rate only matters if nominal wages are indeed rigid. Empirical evidence on wage rigidity is mixed, and differs across countries. Bruno and Sachs [1985], for instance, argue that nominal wages are sticky in the United States, while in Europe, wages tend to be somewhat more sticky in real terms. Furthermore, nominal wages might be rigid with respect to labor market conditions (which mainly affect non-union members, or "outsiders") but not nominal exchange rate movements (which affect the real living standards of "insiders" as-well) [Bofinger (1994)].

Second, exchange rate flexibility only works to the extent that nominal exchange rate movements reflect changes in fundamentals. Two decades of empirical studies have — by and large — failed to uncover such stable links between exchange rate movements and changes in fundamentals (Meese [1990]) This literature, of course, typically refers to floating exchange rates: a regime with fixed, but adjustable parities, may result in desirable real exchange rate changes through nominal exchange rate movements.

Third, a monetary union will result in poorer macroeconomic performance only if shocks affect countries asymmetrically. This is the criterion stressed by Mundell (1961) in his seminal article, and underlies both the theoretical model and the empirical approach adopted here. Yet it should be recognized that the correlation structure of macroeconomic shocks need not remain invariant to the monetary regime. To the extent that adoption of a single currency alters the degree of exchange rate uncertainty, new patterns of trade, investment, and production may emerge. The EU Commission, for instance, asserts that *"EMU will reduce the incidence of country-specific shocks"* [EU Commission (1990:11)]. In contrast, Giersch (1949), Myrdal (1957) and Scitovsky (1958) argue that adoption of common currencies leads to (indeed, is partly motivated by) increased specialization to reap the full benefits of comparative advantage, an argument recently revived by Krugman (1993). The point is hard to decide ex ante: while empirical studies contrasting the US states to Europe indeed find a considerably higher degree of specialization within the US, it is not evident whether the common currency has been the primary cause.

Moreover, monetary (and exchange rate) policy is only equipped to deal with shocks

to *aggregate* GDP or the entire traded sector. As Kenen (1969) notes, such aggregate shocks may be of quite limited importance in well-diversified economies, so that monetary policy loses much of its stabilization role regardless of whether the country joins a monetary union. The empirical evidence of Stockman (1989) and DeGrauwe and Vanhaverbeke (1991) suggests that industry-specific shocks are indeed of first-order magnitude, implying that the nominal exchange rate may be a relatively ineffective stabilization tool.

Fourth, there may be alternative mechanisms for restoring macroeconomic balance in adversely affected regions. If labor is mobile across members of the union, then unemployment can be eliminated by factor flows rather than changes in wage rates.[7] There is *de jure* labor mobility among the European Union countries and among the states of the United States. Whereas actual labor mobility seems very high in the United States [Blanchard and Katz (1992)], cultural, linguistic, and other barriers (such as immediate access to social services or pensions) limit the *de facto* mobility in Europe [Eichengreen (1993)]. Finally, fiscal policy may be an important means of temporarily alleviating the effects of macroeconomic shocks when the exchange rate realignment is not a policy option. Sachs and Sala-i-Martin [1991] argue that larger federal fiscal transfers improve the OCA quality of the US vis a vis Europe. [8]

And fifth, the extent to which real wages need to adjust will depend upon the elasticity of the demand function for the country's output. The assumption that all goods are perfect substitutes is, of course, an extreme one though perhaps not implausible when considering unions of fairly homogenous members. Most of these five factors will tend to reduce the costs of foregoing the possibility of using monetary and exchange rate policy for macroeconomic stabilization. The model developed above, and the empirical results presented below, may thus be considered an upper-bound on the costs of adopting common currencies among union members.

These costs — actual or putative — of adopting a common currency, must be compared

[7] In principle, capital mobility can also alleviate country-specific shocks. As stressed by Masson and Taylor [1994], however, an important distinction needs to be drawn between financial and physical capital mobility. Financial capital can be used to smooth consumption when output is temporarily low. Raising output in depressed regions, however, requires physical capital mobility — or capital accumulation — and this process may be quite slow. If real wages are too high for labor markets to clear, moreover, there may be little incentive for capital to flow to the region anyway.

[8] See however Von Hagen (1991) and Bini and Vori (1993).

to the benefits of a monetary union. As Mundell (1963) asserts, a common currency reduces everyday transactions costs. Not surprisingly, these transactions costs are difficult to measure and quantify. For the case of the EMS, the Commission of the European Union estimates that the total benefits from a move to a single currency will be in the order of "around 0.5% of GDP (ECU 13 to 19 billion per year) for the Community as a whole" [European Commission (1990:21)]. The breakdown of these saving is given in table 1. Corresponding estimates for other geographical regions are not readily available. Taking the Commission's figures as a benchmark, however, it is unlikely that the lowered transactions costs from moving to a single currency would exceed 1% of the total GDP of the countries in the candidate region.

Table 1: Transaction Cost Savings (ECU Bn)

	Low End	High End
1. Financial Transaction Costs	8.2	13.1
Bank Transfers	6.4	10.6
Banknotes, TC, EC, Credit Cards	1.8	2.5
2. Additional Costs To Enterprises	3.6	4.8
3. Reduction Of Cross-Border Payment Costs	1.3	1.3
Total	13.1	19.2

Source: EC Commission (1990).

It seems reasonable to assume that the volume of transactions — and thus the potential saving of transactions costs — will be increasing in the proximity of the members of the union. Indeed, most proposals for monetary unions are for countries which are geographically proximate.[9] There are, of course, several different forms of proximity: the distance between closest borders, the distance between geographic centers or national capitals, as well as concepts of linguistic, or cultural, proximity. One definition of geographic proximity

[9] With some notable exceptions: Panama and Liberia, for instance, have been on a formal dollar standard, while dollarization in some Latin American countries, notably Bolivia, has brought about a "monetary unification from below".

— which is adopted in our empirical work below — requires states to share a common border (for islands, the nearest country can be used). This leads to the idea of *contiguous* monetary unions; that is, unions in which each member shares a border with at least one other member. As discussed below, the requirement of contiguity typically imposes binding constraints on the optimal allocation of countries across monetary unions, and raises the welfare cost of foregone stabilization policy significantly. These higher costs must be weighed against the greater saving on transactions costs that contiguous monetary unions may deliver.

3 The Genetic Algorithm

As noted in the introduction, even for reasonably small numbers of countries, n, (the countries in Europe; the states of the US; or the countries in the world), the number of possible groupings into k monetary unions (for $k \neq 1, n$) , not necessarily of the same size, renders a grid search for the optimum computationally infeasible. We instead adopt a genetic algorithm to search for the optimal allocation. Since the use of genetic algorithms is still quite rare in economics, in this section we briefly describe the algorithm.[10]

Genetic algorithms exploit the optimization principles found in nature: natural selection, gene-combination, and mutation. Populations of candidate solutions are "bred" in each generation using these principles, ideally yielding solutions increasingly better adapted to the problem at hand. For our optimization problem, given a total number of monetary unions, k, and a group of n countries, a *candidate solution* is an $1 \times n$ vector, x, of allocations of the states across the k unions. An entry $x(i) = j$ indicates that the ith state is a member of the jth monetary union.

A *population*, P, consists of p candidate solutions. We begin in the first *generation* with a purely randomly chosen population, P_1 (that is, a $p \times n$ matrix of allocations, where each state is assigned randomly to a union, $j \in \{1, ...k\}$). For each candidate solution, we calculate the *fitness value*, $v(x)$, according to (10). The candidate solutions are then sorted in descending order according to their respective fitness values, $v(x)$, and their ranking assigned to the $1 \times p$ vector, $r(x)$. The solution with the highest fitness value for generation 1, $\hat{x}_1$, together with its fitness value, $\hat{v}_1 = \max\{v(x)\}$, and the average fitness value for the

[10]The classic reference is Holland (1975). Koza (1993) provides a recent programming oriented treatment.

generation, $\bar{v}_1 = avg\{v(x)\}$, are stored.

The next step is to derive the successor generation of solutions. First, natural selection is applied to select the members of the current generation surviving to the next generation. Natural selection is based on a survival function $f(r)$ determining the probability that solution x, with ranking, r, is chosen. $f(r)$ is decreasing in r so that the successor generation is less likely to be composed of low ranking solutions of the current generation. Solutions chosen to survive are not eliminated from the original pool, thus the best solutions of generation i are likely to be represented several times in the successor generation. To ensure continuity, the best solution from the current generation is always included at least once in the successor generation.

The new population of solutions, $P_1' = \{x'\}$ is again sorted in descending order, r' before allowing a fraction of these solutions to "mate" with their adjacent solutions. Mating entails exchanging part of the solution vector. Specifically, after a random switching point, $1 < l < n$ has been chosen, the $l+1, ...n$, elements of solution of solutions s and $s+1$ are swapped, generating a new population of solutions, $P_1'' = \{x''\}$. Finally, in order to emulate natural mutations, a few (randomly chosen) elements of x'' are replaced by random integers, $z \in \{1, ..k\}$, yielding the starting population for the next generation P_2.

The entire process is now repeated. At each generation, the algorithm yields an optimal solution, $\hat{x}_1, \hat{x}_2, \hat{x}_3, ...\hat{x}_g$ together with an associated fitness value, $\hat{v}_1, \hat{v}_2, \hat{v}_3, ...\hat{v}_g$ .While the quality of the best solution improves rapidly before stabilizing, there is no easy way to gauge whether a local or a global optimum has been found. Indeed, research in evolutionary biology suggest a fairly common occurrence of prolonged periods of apparent stability suddenly interrupted by burst of rapid improvements, reflecting a gradual quality improvement in the *pool* of solution finally reaching a critical level enabling further "evolutionary spurts".

We used a number of tools to maximize the likelihood of finding a global optima. First, within the solution process itself, the combination of a constant fitness value of the best solution and an average fitness of the solution pool, $\bar{v}$, fluctuating within very narrow band over a prolonged sequence of generations provides evidence in favor of convergence and was used as a termination criterion. Second, to control explicitly for the possibility of a local optimum, the rate at which cells are randomly mutated is positively related to the stability of the average fitness value, thereby injecting additional variability into the solution pool in

times of apparent or real stability. Finally, the algorithm has been tested on optimization problems which are sufficiently small that an explicit grid search can be used. In each case, the algorithm found the correct solution very rapidly, and the convergence criteria were sufficient to distinguish between local and global optima.

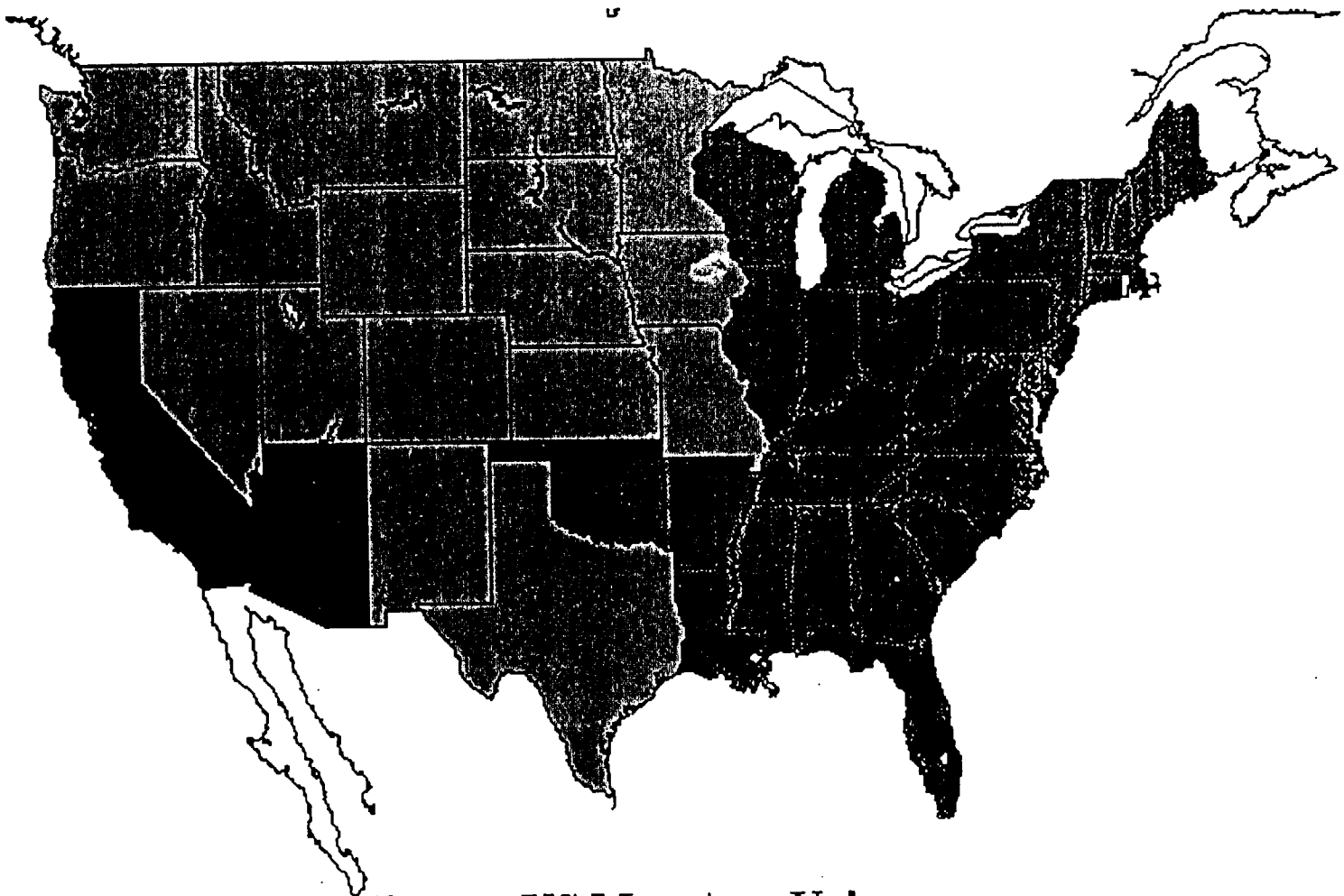
4 Empirical Results

The methods described above were used to calculate the optimal currency unions for six different geographic/economic regions: (1) the states of the USA, (2) 20 West European countries, (3) the Group of Seven major industrial nations, (4) the members of the CFA, (5) the successor states of the former Rouble zone and (6) 120 countries of the world at large. These regions cover most, though by no means all, of actual or proposed monetary unions, fixed exchange rate regimes, or common currency areas.

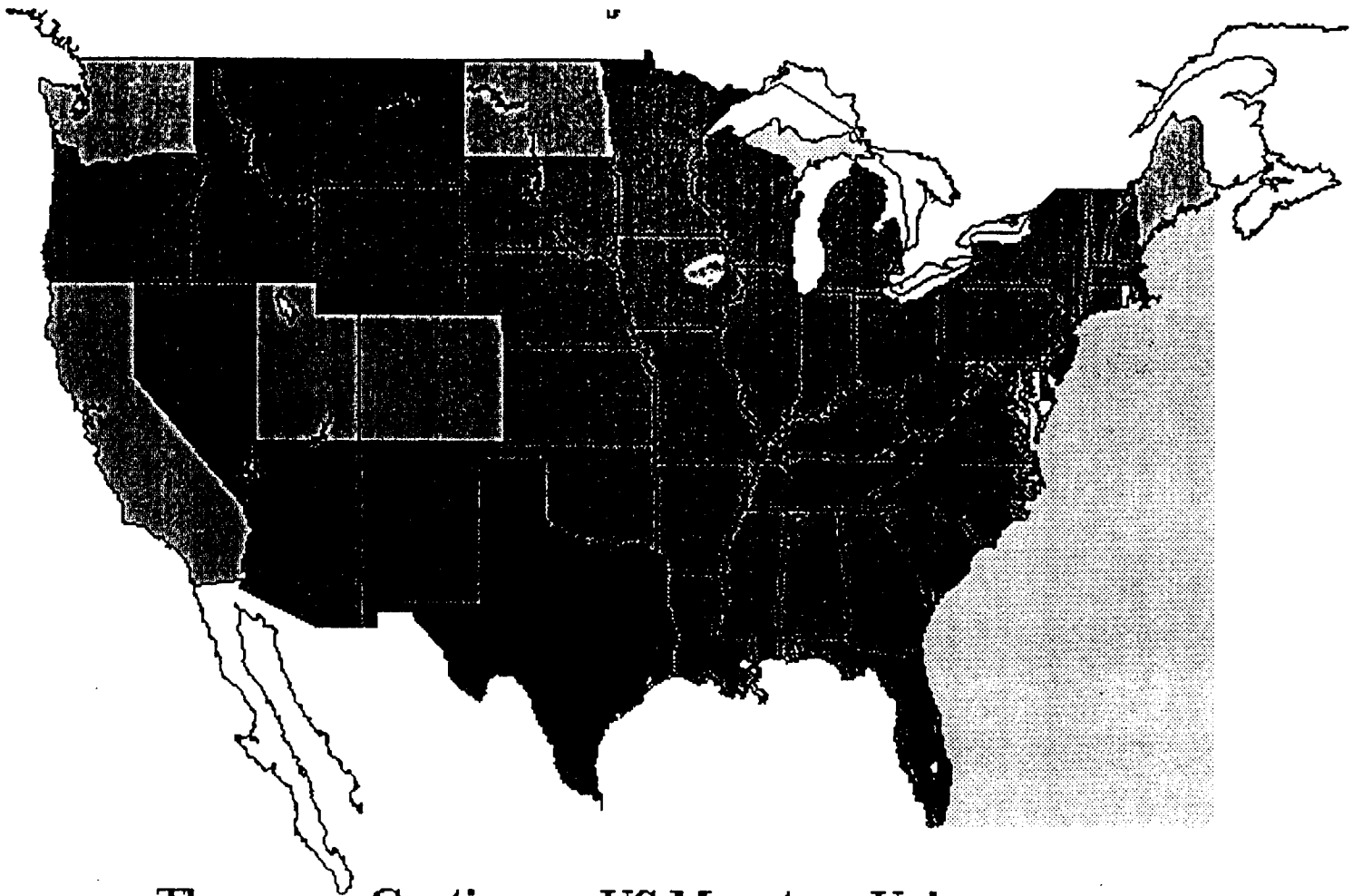
4.1 States of the USA

We begin with the 50 states of the USA, using the annual constant dollar data on Gross State Product (GSP) published by the Bureau of Economic Analysis. Since the United States are already a single currency area, the data on GSP are the "within" monetary union levels of output, $\hat{Q}$. Equation (8) can be inverted (assuming each of the fifty states belongs to a single currency union) to calculate the GSP which would have prevailed had these states not shared a common currency.

Table 2 reports the loss from forgone macroeconomic stabilization, expressed as a percentage of US GDP, against the number of independent currencies. With fifty separate currencies this cost is, by definition, equal to zero. Adopting a single currency, in contrast, costs the US states some 2.6 percent of GSP each year. These costs fall quite rapidly as the number of currencies increases: with five currencies the cost is approximately 1.5 percent of GSP, with ten currencies it is 1.2 percent, and it is less than 1 percent of GSP when there are fifteen currencies, or more. Table 3 reports the optimal state groups for various values of k, the total number of monetary unions. As an example, the optimal groups for three contiguous and non-contiguous monetary unions are illustrated in figures 1a and 1b. The results are strikingly reminiscent of Mundell's concept of a western and an eastern dollar, with a California dollar rounding out the picture.



Three Contiguous US Monetary Unions



Three non-Contiguous US Monetary Unions

Turning to the non-contiguous case, the loss minimizing solution is seen to entail very different sized currency areas. California, Colorado, Hawaii, Maine, North Dakota, Utah and Washington form one currency area. Texas has its own currency. All of the remaining states share the third currency. The optimal decomposition reflects two factors: the size of the candidate members, and their covariance structure. It is thus tempting to conclude that the behavior of the Texan economy — and to a lesser degree, that of California — is qualitatively different from the other US states, requiring a separate Texan dollar for any number of currencies greater than three. Yet, as table 3 reveals, as the number of currencies is increased parametrically, the optimal grouping does not simply involve "breaking-up" the larger currency areas into smaller components, but rather the combination of member of different currency unions into new groups: with twenty currency areas, for instance, Texas is paired with Hawaii, Missouri, Utah, and Wyoming. This result is well-known in the theory of clubs: when the number of clubs is increased, the new groups often consist of members from different existing clubs.[11]

Next, we consider the effects of restricting monetary unions to be geographically contiguous, in the sense defined above. When there is either a single currency area, or fifty currency areas, the optimal contiguous and non-contiguous monetary unions obviously coincide. More generally, requiring contiguous unions restricts the allocation of states across unions and lowers the attainable level of welfare. Table 2 compares the losses for various numbers of monetary unions.

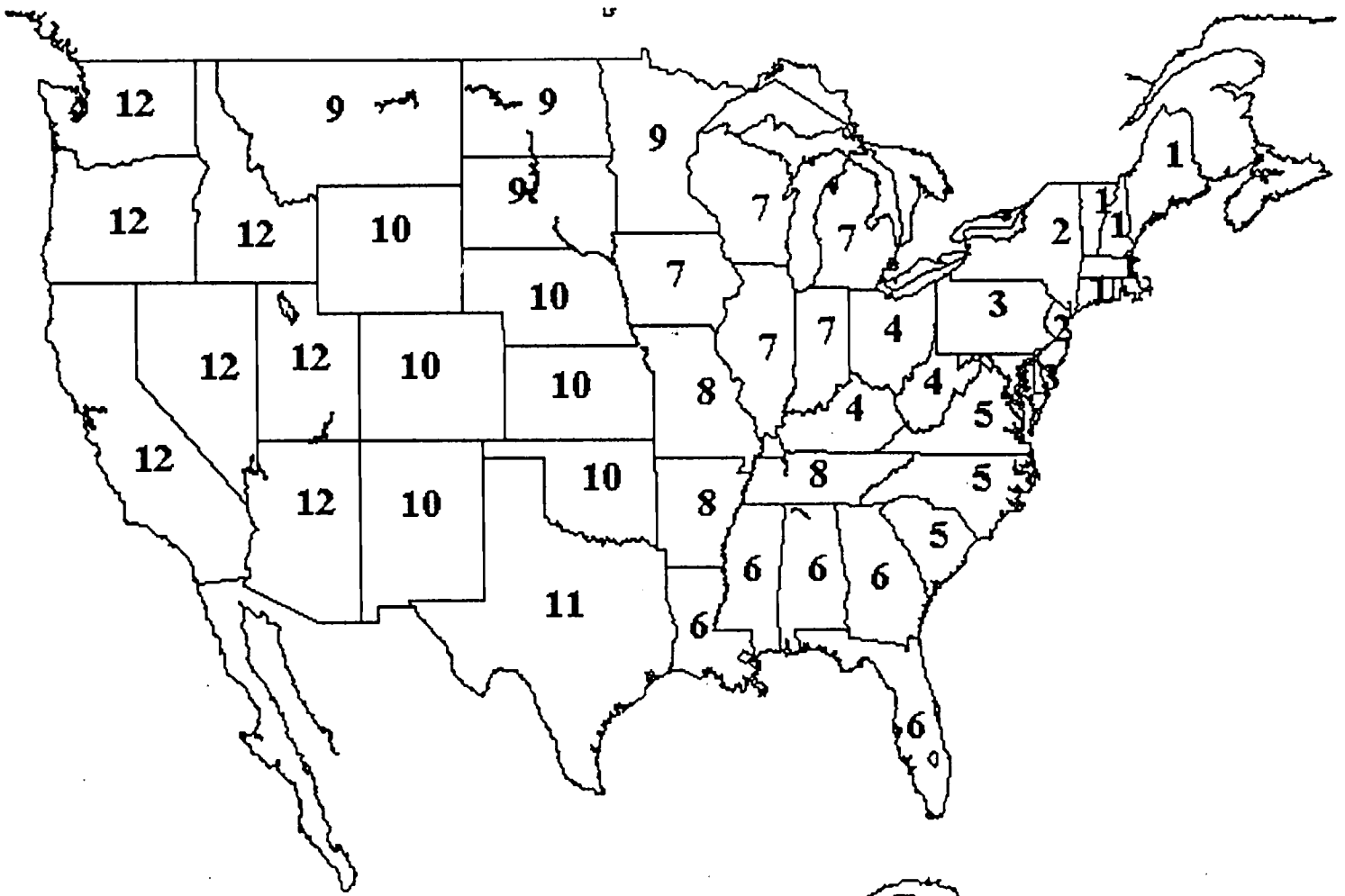
Table 2: Comparative Losses: Contiguous Vs. Non-Contiguous

Unions	1	2	5	10	20	30	40	50
Contiguous	2.63	2.54	2.08	1.79	0.08	0.08	0.02	0.00
Non-Contiguous	2.63	2.38	1.68	1.26	0.07	0.04	0.02	0.00

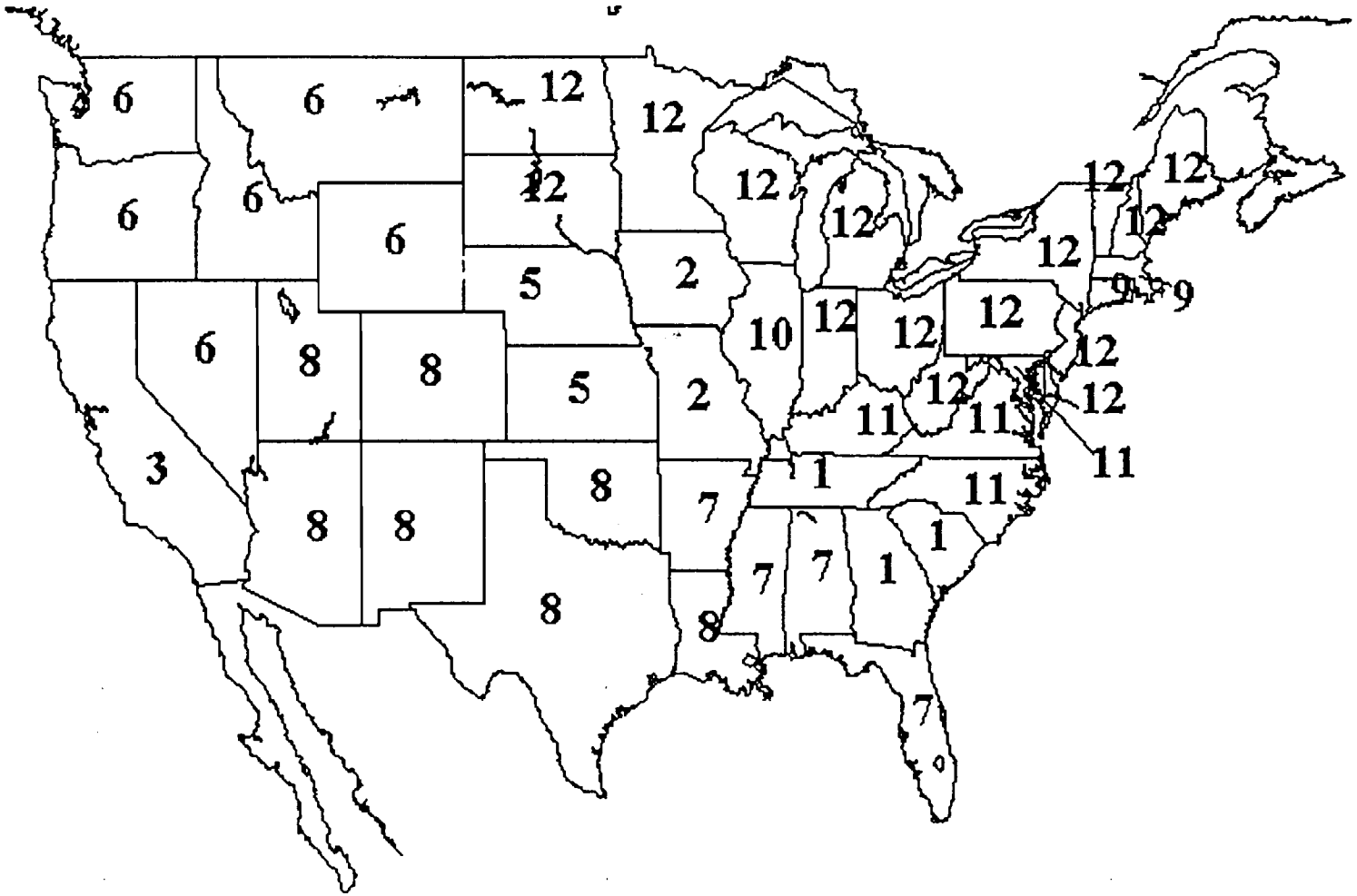
[11] See Cassella [1994] for a derivation of this result in a theoretical model of optimal club-formation.

Table 2: United States

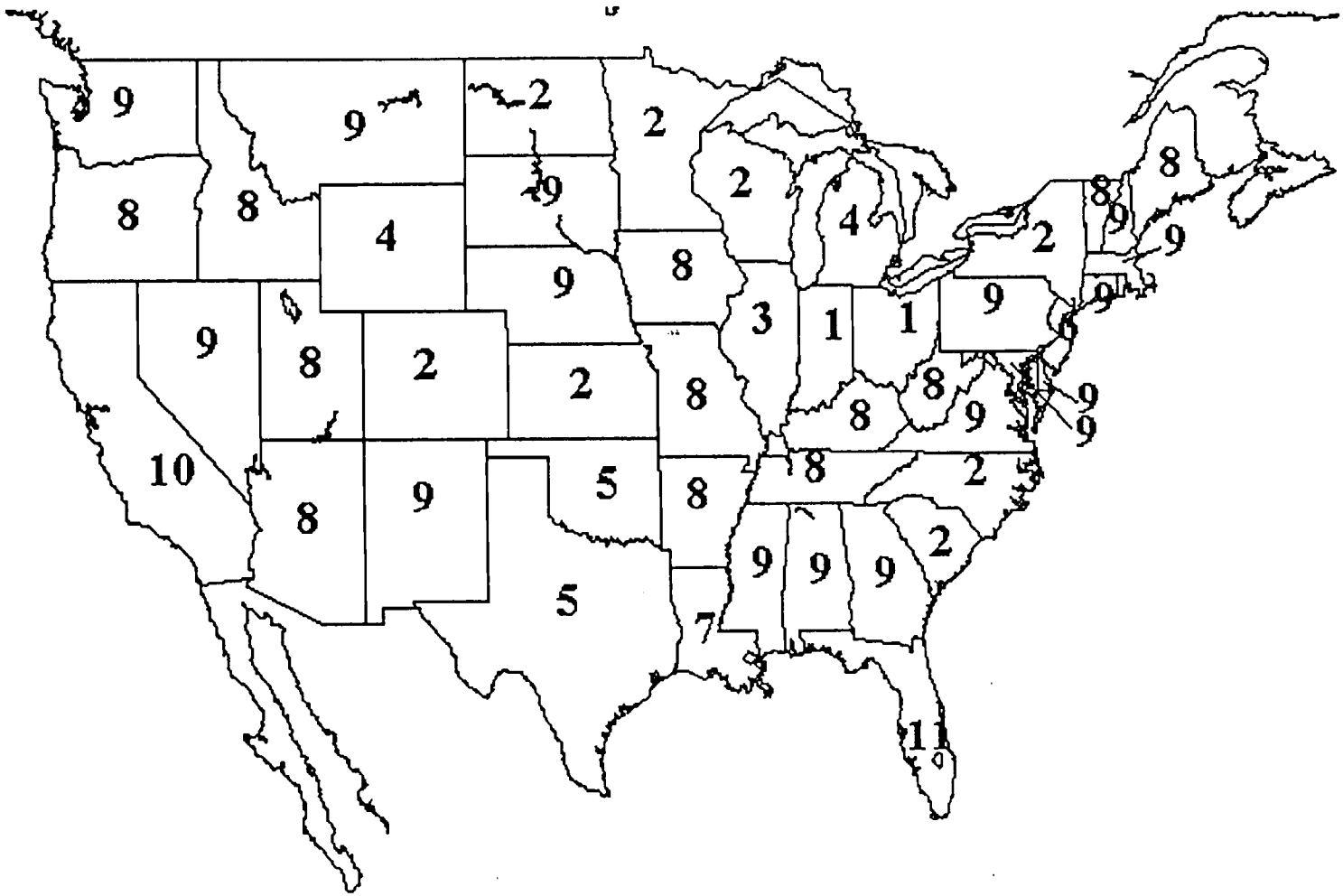
Non-Contiguous				Contiguous			
2 Unions	3 Unions	5 Unions	20 Unions	2 Unions	3 Unions	5 Unions	20 Unions
Alabama	California	Alabama	Alabama	Alabama	Alabama	Colorado	Alabama
Alaska	Colorado	Alaska	Delaware	Alaska	Arkansas	Idaho	Delaware
Arizona	Hawaii	Arizona	Minnesota	Arizona	Connecticut	Illinois	Georgia
Arkansas	Maine	Arkansas	Montana	Arkansas	Delaware	Indiana	N. Carolina
California	N. Dakota	Georgia	Nebraska	California	Florida	Iowa	Pennsylvania
Colorado	Utah	Illinois	Oregon	Colorado	Georgia	Kansas	S. Carolina
Connecticut	Washington	Indiana	S. Carolina	Connecticut	Illinois	Louisiana	Virginia
Delaware		Iowa		Delaware	Indiana	Minnesota	W. Virginia
Florida	Alabama	Kansas	Arizona	Florida	Kentucky	Montana	
Georgia	Alaska	Kentucky	Arkansas	Georgia	Louisiana	N. Dakota	Connecticut
Hawaii	Arizona	Minnesota	Colorado	Hawaii	Maine	N. Mexico	Maine
Idaho	Arkansas	Mississippi	Idaho	Idaho	Maryland	Nevada	Massachusetts
Illinois	Connecticut	Missouri	N. Dakota	Iowa	Massachusetts	Oklahoma	N. Hampshire
Kansas	Delaware	N. Mexico	Washington	Kansas	Michigan	S. Dakota	N. York
Kentucky	Florida	Ohio		Kentucky	Mississippi	Texas	Rhode Island
Louisiana	Georgia	Oregon	Hawaii	Louisiana	N. Carolina	Utah	Vermont
Maine	Idaho	Pennsylvania	Missouri	Maine	N. Hampshire	Wisconsin	
Maryland	Illinois	Rhode Island	Texas	Maryland	N. Jersey		Colorado
Massachusetts	Indiana	S. Carolina	Utah	Massachusetts	N. York	Connecticut	Iowa
Minnesota	Iowa	S. Dakota	Wyoming	Michigan	Ohio	Delaware	Nebraska
Mississippi	Kansas	Tennesse		Mississippi	Oklahoma	Maine	Oklahoma
Missouri	Kentucky	W. Virginia	Kansas	Missouri	Pennsylvania	Maryland	Texas
Montana	Louisiana	Wisconsin	Mississippi	Montana	Rhode Island	Massachusetts	Wyoming
N. Carolina	Maryland		Tennesse	N. Carolina	S. Carolina	N. Carolina	
N. Dakota	Massachusetts	Connecticut	W. Virginia	N. Dakota	Tennesse	N. Hampshire	Arkansas
N. Hampshire	Michigan	Delaware	Wisconsin	N. Hampshire	Vermont	N. Jersey	Kansas
N. Jersey	Minnesota	Florida		N. Jersey	Virginia	N. York	Kentucky
N. Mexico	Mississippi	Maryland	Connecticut	N. Mexico	W. Virginia	Pennsylvania	Mississippi
N. York	Missouri	Massachusetts	Maine	N. York	Wisconsin	Rhode Island	Missouri
Nebraska	Montana	N. Jersey	Massachusetts	Nebraska		Vermont	Tennesse
Nevada	N. Carolina	Nebraska	Vermont	Nevada	Alaska	Virginia	
Oklahoma	N. Hampshire	Nevada		Ohio	Colorado	W. Virginia	Idaho
Oregon	N. Jersey	Vermont	Maryland	Oklahoma	Idaho		Minnesota
Pennsylvania	N. Mexico	Virginia	Pennsylvania	Oregon	Iowa	Alabama	Montana
Rhode Island	N. York	Wyoming	Rhode Island	Pennsylvania	Kansas	Arkansas	N. Dakota
S. Carolina	Nebraska		Virginia	Rhode Island	Minnesota	Florida	S. Dakota
S. Dakota	Nevada	Idaho		S. Carolina	Missouri	Georgia	
Texas	Ohio	Louisiana	Iowa	Tennesse	Montana	Mississippi	Illinois
Utah	Oklahoma	Montana	N. Carolina	Texas	N. Dakota	S. Carolina	Wisconsin
Vermont	Oregon	N. Carolina	N. York	Utah	N. Mexico	Tennesse	
Virginia	Pennsylvania	N. Hampshire	S. Dakota	Vermont	Nebraska		Indiana
W. Virginia	Rhode Island	N. York		Virginia	Nevada	Alaska	Ohio
Washington	S. Carolina	Oklahoma	Kentucky	W. Virginia	Oregon	Arizona	
Wisconsin	S. Dakota	Texas	N. Hampshire	Washington	S. Dakota	California	Hawaii
	Tennesse				Texas	Hawaii	Washington
Indiana	Vermont	California	Indiana	Illinois	Utah	Oregon	
Iowa	Virginia	Colorado	Ohio	Indiana	Washington	Washington	Alaska
Michigan	W. Virginia	Hawaii		Minnesota	Wyoming		
Ohio	Wisconsin	Maine	Illinois	S. Dakota		Kentucky	Arizona
Tennesse		N. Dakota		Wisconsin	Arizona	Michigan	
Wyoming	Wyoming	Utah	Oklahoma	Wyoming	California	Missouri	California
		Washington			Hawaii	Nebraska	
			Nevada			Ohio	Michigan
		Michigan				Wyoming	
			California				N. Jersey
			Florida				Louisiana
			Louisiana				Oregon
			Alaska				Florida
			N. Jersey				Maryland
			Georgia				N. Mexico
			Michigan				Nevada
			N. Mexico				Utah



Twelve Federal Reserve Districts



Twelve Contiguous US Monetary Unions



Twelve non-Contiguous US Monetary Unions

The maximum difference between contiguous and non-contiguous monetary unions is in the order of 80% of the non-contiguous loss (that is, a loss of 0.84% of GSP instead of 0.46% of GSP). As a specific case, the three panels of figure 2 illustrate the optimal grouping of states into 12 areas, contrasting the contiguous and the non-contiguous optimum with the 12 Federal Reserve Districts. A comparison reveals significant differences. Restricting districts to be contiguous, California rather than Texas becomes a lone rider, most other groupings are distinctly different from the current Federal Reserve System. Yet -among the subset of contiguous allocations- the Federal Reserve System is quite satisfactory: changing to the optimal allocation only yields a welfare gain of 0.04, from 1.76 to 1.72 percent of GDP. Major welfare benefits are however to be had if reserve zones were not restricted to be contiguous: moving from the best 12 member contiguous to the best 12 member non-contiguous allocation reduces the cost by more than a third, 1.72 down to 1.00 percent of GDP.

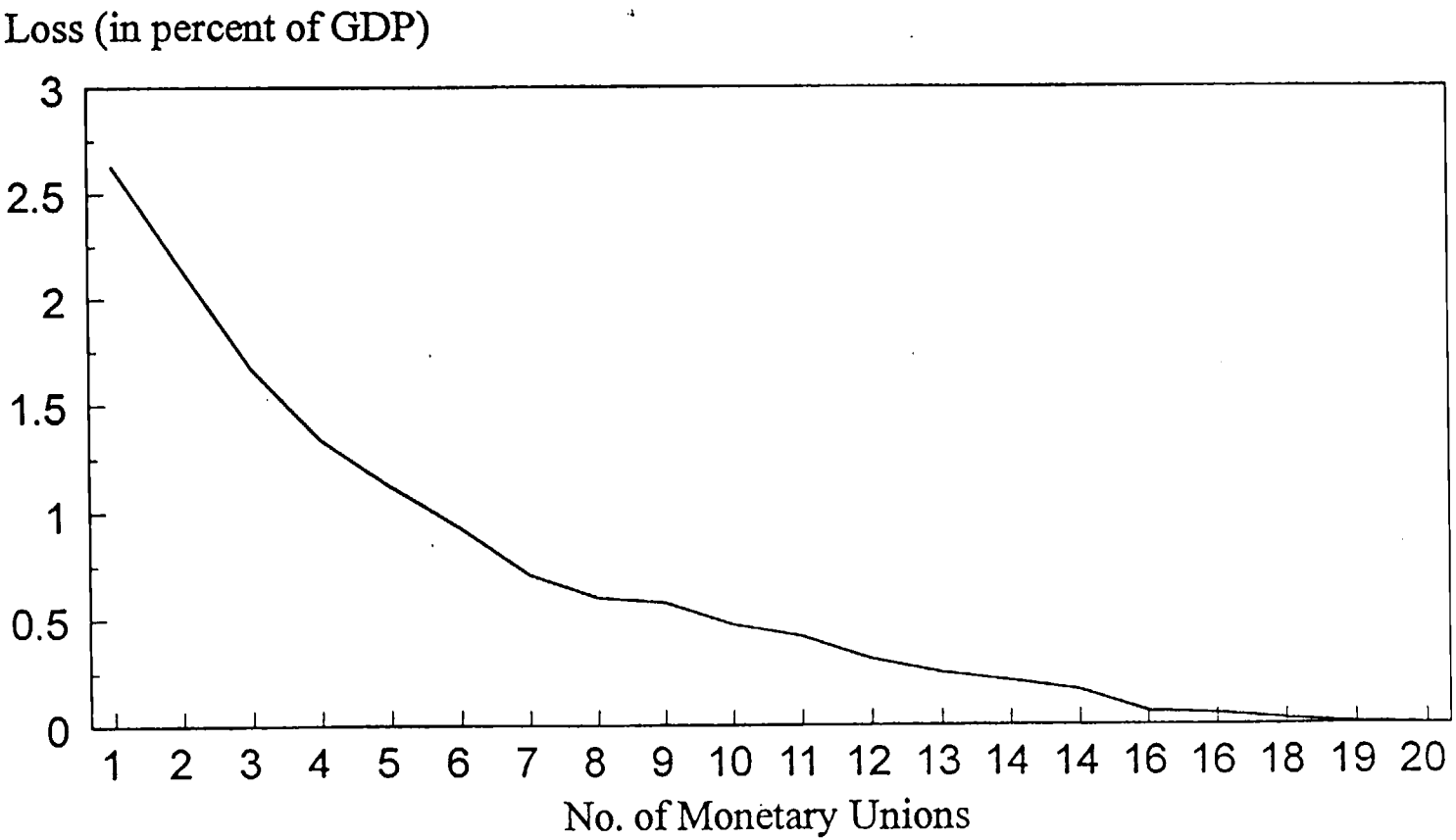
4.2 The European Countries

Perhaps the most exciting developments in monetary integration during recent years have been in Western Europe where the members of the European Union have been striving towards rigidly fixed exchange rates and, ultimately, a single currency — motivating a substantial literature on the merits of Europe as an optimal currency area.[12]

As an increase in the current union membership is likely, we consider the costs of adopting a single currency for the existing European Union members (Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and the UK) as well as for a group of 20 European countries (the EU12 plus Austria, Cyprus, Finland, Iceland, Norway, Sweden, Switzerland, and Turkey). The annual constant price GDP data for the period 1960-1988 are taken from the Summers-Heston data set. Figures 3 and 4 plot the stabilization costs of a single currency for all 20 European countries and the twelve existing EU members. In each case, the cost is about 2.5% of GDP (it is slightly higher for the 20 countries), roughly similar to the finding for the 50 US States. In terms of foregone stabilization policy benefits, therefore, the European Union is *not* a

[12]See Bayoumi and Eichengreen (1992). Bini Smaghi and Vori (1993), Bofinger (1994), Canzoneri and Rogers (1991), DeGrauwe and Vanhaverbeke (1991), Eichengreen (1990a,b), EC Commission (1990), *inter alia*.

Twenty European Countries



European Monetary System
12 Countries

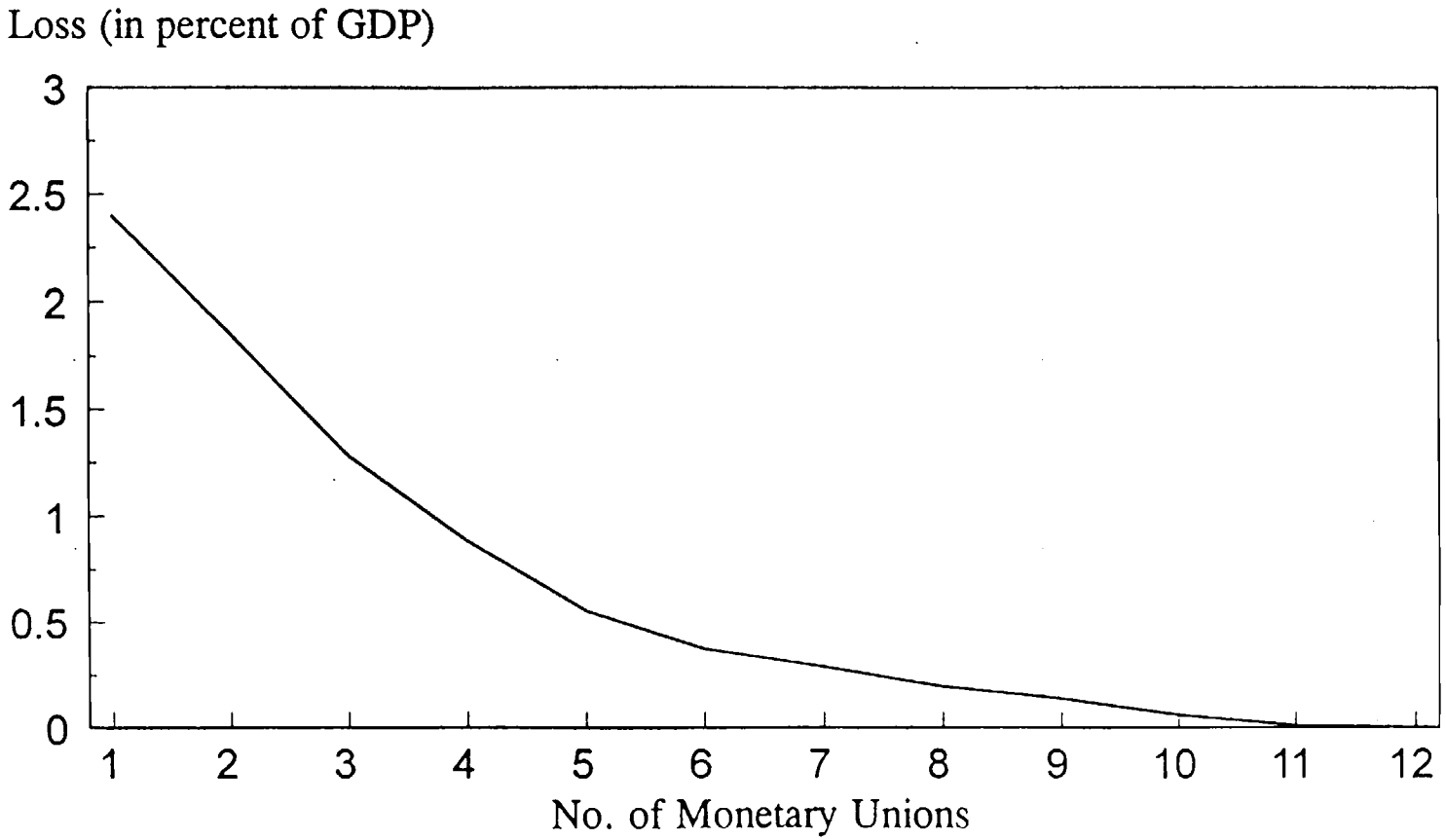
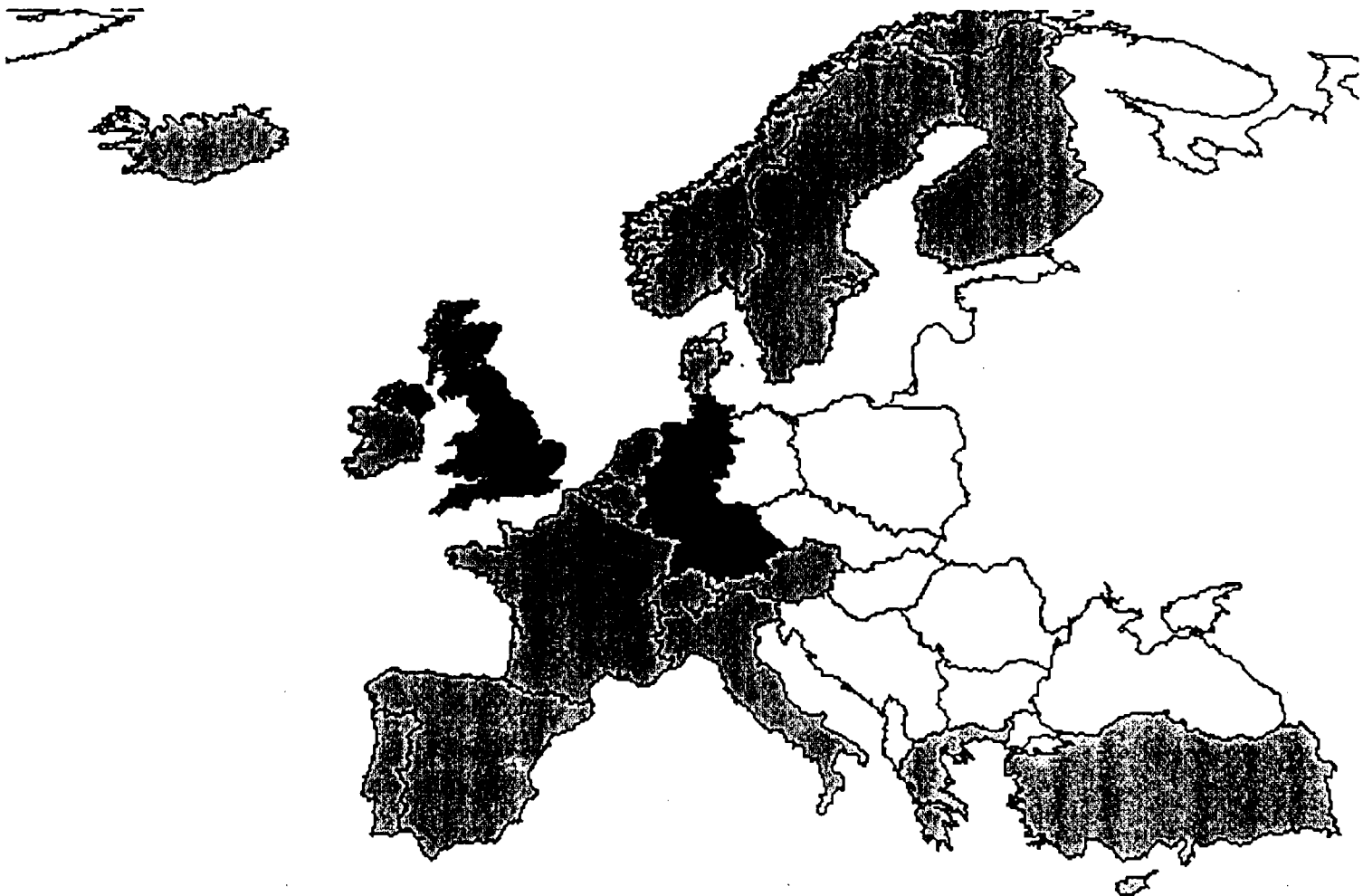


Table 5: Europe

European Monetary System									
			2 Unions	4 Unions	6 Unions	8 Unions			
			Belgium Denmark France Greece Ireland Italy Luxembourg Netherlands Portugal Spain U.K Germany	Belgium Denmark France Greece Ireland Luxembourg Netherlands Portugal Spain —— Germany U.k. Italy	Belgium Denmark Greece Ireland Netherlands Portugal Luxembourg Spain —— U.K Germany France Italy	Denmark Greece Ireland Luxembourg Portugal —— Germany France Italy Belgium Netherlands U.K. Spain			
Europe Non-Contiguous					Europe Contiguous				
2 Unions	3 Unions	4 Unions	6 Unions	8 Unions	2 Unions	3 Unions	4 Unions	6 Unions	8 Unions
Austria Belgium Cyprus Denmark Finland France Greece Iceland Ireland Italy Luxemb. Netherl. Norway Portugal Spain Sweden Switzerl. Turkey U.K. Germany	Austria Belgium Cyprus Denmark Finland France Greece Iceland Ireland Italy Luxemb. Netherl. Norway Portugal Spain Sweden Switzerl. Turkey —— Germany UK	Austria Belgium Cyprus Denmark Finland France Greece Ireland Luxemb. Netherl. Norway Portugal Spain Sweden Switzerl. Turkey Germany Iceland —— Italy U.K.	Austria Belgium Cyprus Denmark Greece Iceland Ireland Netherl. Norway Portugal Sweden Switzerl. Turkey Luxemb. Spain Finland France —— Italy U.K. Germany	Belgium Denmark Finland Greece Norway Portugal Sweden Switzerl. Austria Ireland Netherl. Cyprus Luxemb. U.K. France Iceland —— Germany Italy Spain Turkey	Austria Belgium Denmark Finland France Germany Iceland Ireland Italy Luxemb. Netherl. Norway Portugal Spain Sweden Switzerl. U.K. Cyprus Greece Turkey	Austria Belgium Denmark Finland France Germany Iceland Ireland Luxemb. Netherl. Norway Portugal Spain Sweden U.K. Cyprus Greece Turkey —— Switzerl. Italy	Austria Denmark France Germany Ireland Luxemb. Netherl. Portugal Spain Switzerl. U.K. Iceland Norway Sweden Cyprus Greece Turkey —— Belgium Finland Italy	Austria France Italy Luxemb. Portugal Spain Switzerl. Cyprus Greece Turkey Belgium Netherl. Finland Norway Ireland U.K. Denmark Germany —— Sweden Iceland

Single currency unions listed below "——".



Three non-Contiguous European Monetary Unions

worse candidate for a monetary union than are the US states. (Of course, the transactions benefits may be lower in Europe, and the scope for other forms of stabilization — through fiscal transfers, for instance — may be more limited). Notably, the current EU members do not appear to be better candidates for a single currency than an expanded union would be.

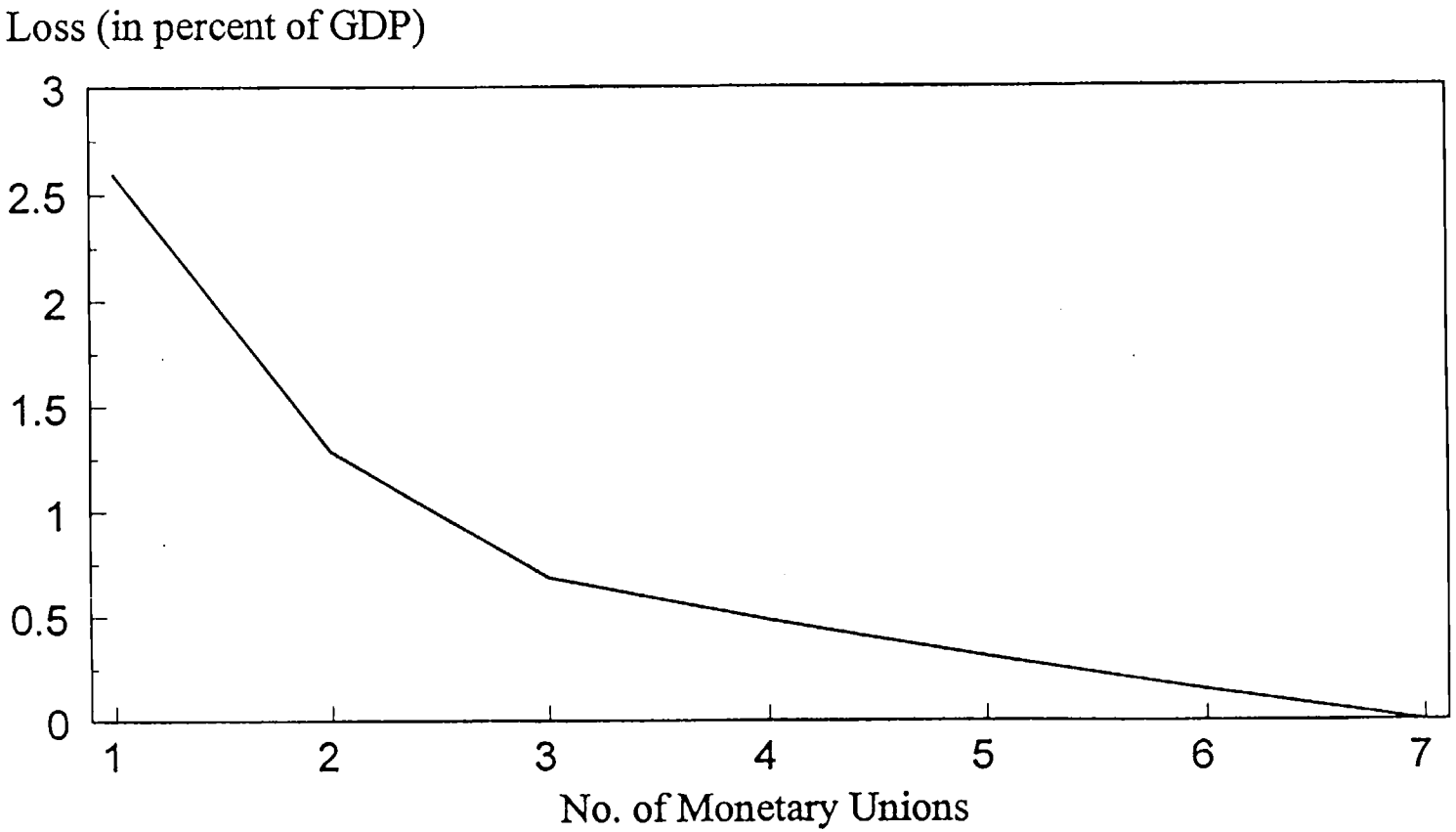
Bringing the stabilization cost below 1% of GDP requires 6 currencies for the 20 European countries. Bringing the stabilization cost below 0.5% of GDP — the European Commission's estimate of the transactions costs savings from adopting a single currency — would require 9 separate currencies for the enlarged EU, and at least 6 currencies for the existing European Union. At least according to these estimates, therefore, monetary integration for the European Union would not be worthwhile.

Table 5 report the optimal groupings of the EU12 and EU20 countries for various numbers of independent currencies. In light of the emphasis on extending the "Deutschemark zone" implicit in the European Monetary System to form the basis of the single currency, the results are remarkable. As long as there are two or more currencies, Germany never forms a currency union with any other European country. While pegging to the DM may certainly bring benefits in the form of anti-inflationary credibility, it is not optimal from the perspective of stabilizing output against macroeconomic shocks. The other major outlier — perhaps less surprisingly — is the United Kingdom, which does not form a currency union with other countries as long as there are three or more currencies for the EU. The table also shows the optimal country groupings when monetary unions must be adjacent. Once again, these are quite different from the unconstrained optimal allocation, and the welfare loss is correspondingly higher. As an illustration, figure 5 display the optimal non-contiguous unions for the case of three monies. Germany and the United Kingdom remain independent, while the remaining countries form a monetary union, not unlike (if in an extreme sense) the core periphery model advocated by proponents of two stage EMU.

4.3 The Group of Seven Major Industrialized Countries

The volatility of nominal exchange rates since the breakdown of the Bretton Woods agreement has engendered a number of proposals for greater exchange rate fixity, at least among the major industrialized countries. These proposals have generally foundered on the poten-

Group of Seven Major Industrialized Countries



tial loss of sovereignty and monetary independence that a system of fixed exchange rates — let alone a single currency — would entail. As a first step towards evaluating the idea of a return to fixed exchange rates it is useful to calculate the costs from foregone stabilization policy, as well as the optimal partners in a more modest scheme in which there would be, say, three currencies, shared by the seven major industrialized countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States).

Table 6: Group Of Seven

Number Of Unions	Two	Three	Four	Five	Six
Members	Canada France Germany Italy U.K. U.S.A. —— Japan	Canada France Germany Italy U.K. —— U.S.A. Japan	Canada France Germany Italy —— U.K. U.S.A. Japan	Canada France Italy —— Germany U.K. Japan U.S.A.	Canada U.S.A. —— France U.K. Italy Japan Germany
Cost (% GDP)	1.29	0.68	0.48	0.31	0.15

Single member currency unions listed below "——".

Performing the calculations, yields a 2.6% of G7 GDP cost of adopting a single currency (Figure 6). With three currencies, however, this falls to 0.75% of G7 GDP. Again, as a fraction of GDP, these are not very different from the results on the US states or the European countries, above. The optimal currency areas, given in table 6, are largely intuitive. If the G-7 share six currencies then the United States and Canada form an optimal bloc and the others maintain separate currencies. With five currency areas, Canada, France and Italy, form a second optimum currency area; with four currencies, Germany joins this continental European bloc; followed by the United Kingdom when there are three currencies. If there are only two currency areas, the US joins the European bloc,d while Japan continues to maintain a separate currency.

4.4 The CFA

One of the most successful currency unions, at least in terms of longevity, is the CFA zone of African countries.[13] While the monetary union has survived the revaluation of the external peg, the French Franc, the CFA Franc zone is generally not viewed as an optimal currency area, reflecting the degree to which the non-diversified economies rely on different primary product exports and hence their susceptibility to asymmetric shocks [Bhatia (1985), Boughton (1991), Devarajan and Rodrick (1991)].

Table 7: CFA

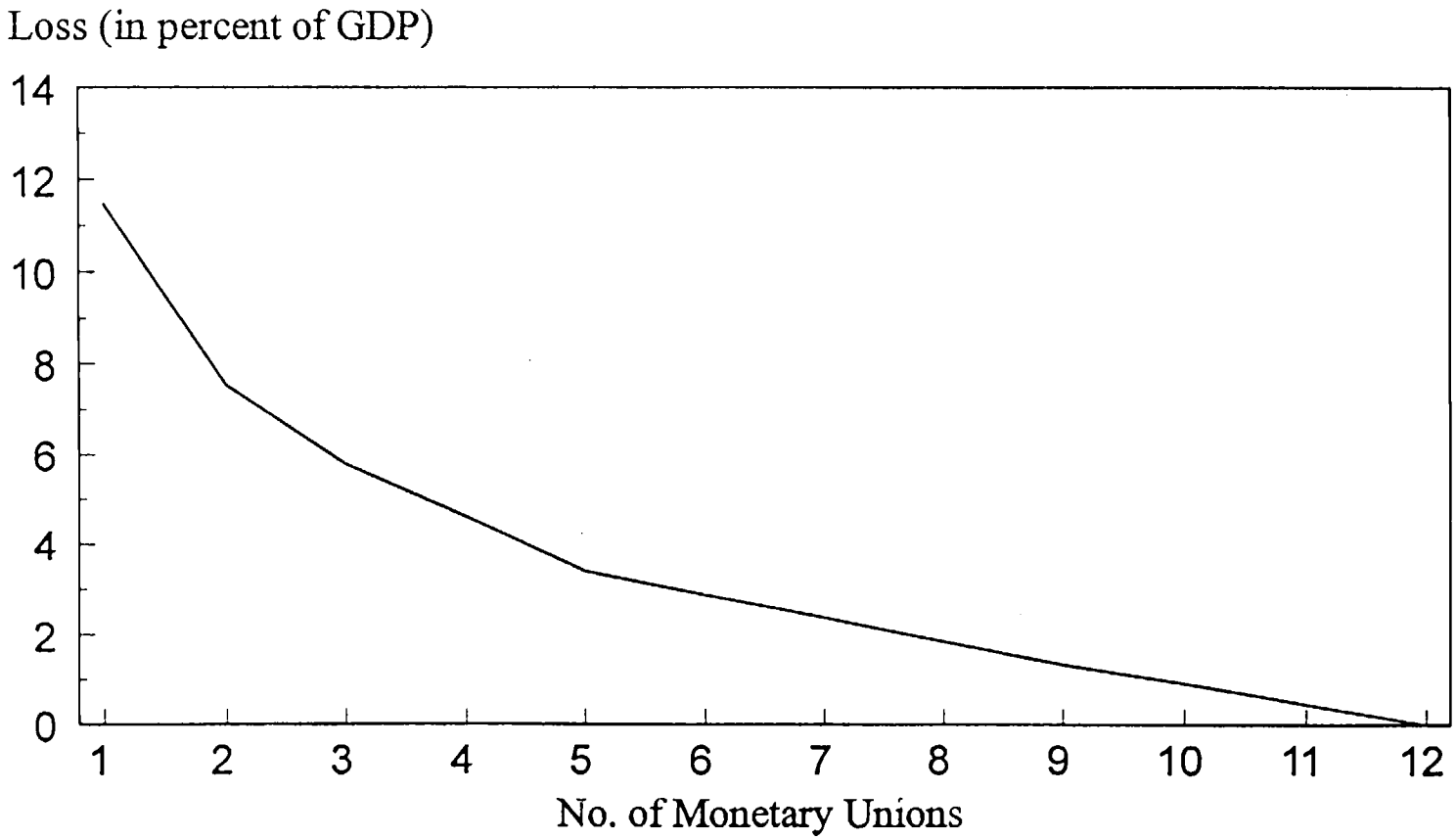
2 Unions	4 Unions	6 Unions	8 Unions
Benin	Burkina Faso	Burkina Faso	Congo
Burkina Faso	C.A.R.	Chad	Eq. Guinea
C.A.R.	Cameroon	Mali	Mali
Cameroon	Chad	Senegal	
Chad	Senegal		Burkina F
Congo		Benin	C.A.R.
Eq. Guinea	Benin	Congo	Senegal
Gabon	Congo	Eq. Guinea	——
Mali	Eq. Guinea		Chad
Niger	Mali	C.A.R.	Niger
Senegal	Niger	Cameroon	Gabon
——	——	——	Bénin
Ivory Coast	Gabon	Niger	Ivory Coast
	Ivory Coast	Gabon	Cameroon
		Ivory Coast	

Single member currency unions listed below "——".

This is borne out in figure 6, which shows the cost of adopting common currencies,

[13] While the CFA actually consists of two currency unions, the West African Monetary Union (comprising Benin, Burkina Faso, Cote d'Ivoire, Mali, Niger, Senegal, Togo) and the Central African Monetary Union (comprising Cameroon, Chad, Congo, Central African Republic, Equatorial Guinea) the two halves have always been linked by a fixed parity.

Twelve CFA Countries



again calculated based on data from the Summers and Heston dataset. The figure reveals that the loss in terms of foregone macroeconomic stabilization are significantly higher than the corresponding costs for the US, the European countries, or even the G-7. Maintaining a single currency costs some 11 percent of GDP, while two currencies costs almost 8 percent of GDP. To bring the stabilization costs below 1 percent of GDP would require eleven separate currencies for the twelve countries. The optimal country groupings, reported in table 9, show that Cote d'Ivoire — which never shares its currency when there are two or more currency areas — is the main outlier from the other members of the CFA zone. As Boughton (1991, 1993) notes, the case for maintaining the CFA franc zone thus cannot rest on the standard criteria of an OCA, but must rather be based on the credibility, inflation and competitiveness advantages obtained through the peg of the entire zone to the French Franc.

4.5 Successor States of the Former Soviet Union

Following the collapse of the Soviet Union, a fifteen member monetary union came into existence at the end of 1991. The extreme degree of specialization, coupled with continued reliance on primary products, led most observers to reject the former Soviet Union as an optimum currency area. [14] While a continuation of the ruble zone was widely advocated — and indeed formed the declared policy objective of the Bretton Woods institutions until the failure of the Tashkent Conference - the support was not based on classical OCA grounds, but on the short- to medium term desirability of sustaining the established ruble zone as a transitional system in favor of a fragmented system with multiple, internationally unrecognized, and hyperinflating currencies likely to further exacerbate the impending trade collapse [Gros *et al.* (1992), Gros (1993), IMF (1994), Wolf (1992)].

Beggar thy neighbor strategies by republican central banks able to extend credits to local enterprises, an increasing unwillingness of Russia to accept the implied net resource transfer, and the political benefits of introducing new national monies, however, doomed efforts to prop up the ruble zone. Following the exit of the Baltic states, Russia's decision to establish limits on interstate credit began the process of the ruble zone fragmentation, with all republics now having introduced versions of separate national currencies [Hanson

[14] Indeed, given the high internal specialization, it is hard to argue that Russia by itself constitutes an optimum currency area.

(1993)].[15]

Data on republican output is scarce, covers only seven years and is — due to the *ex post* reconstruction by the World Bank based on raw data collected by the planning organizations — subject to significant "confidence intervals". Even these data were only available for twelve successor republics. A further important qualification of the data concerns their time consistency: the historical correlation of output movements reflects decisions made under a system of central planning, one might suspect that the correlation matrix will change to some degree as the countries adopt more market orientated economic systems. The results reported in table 8 must thus be viewed as only indicative.

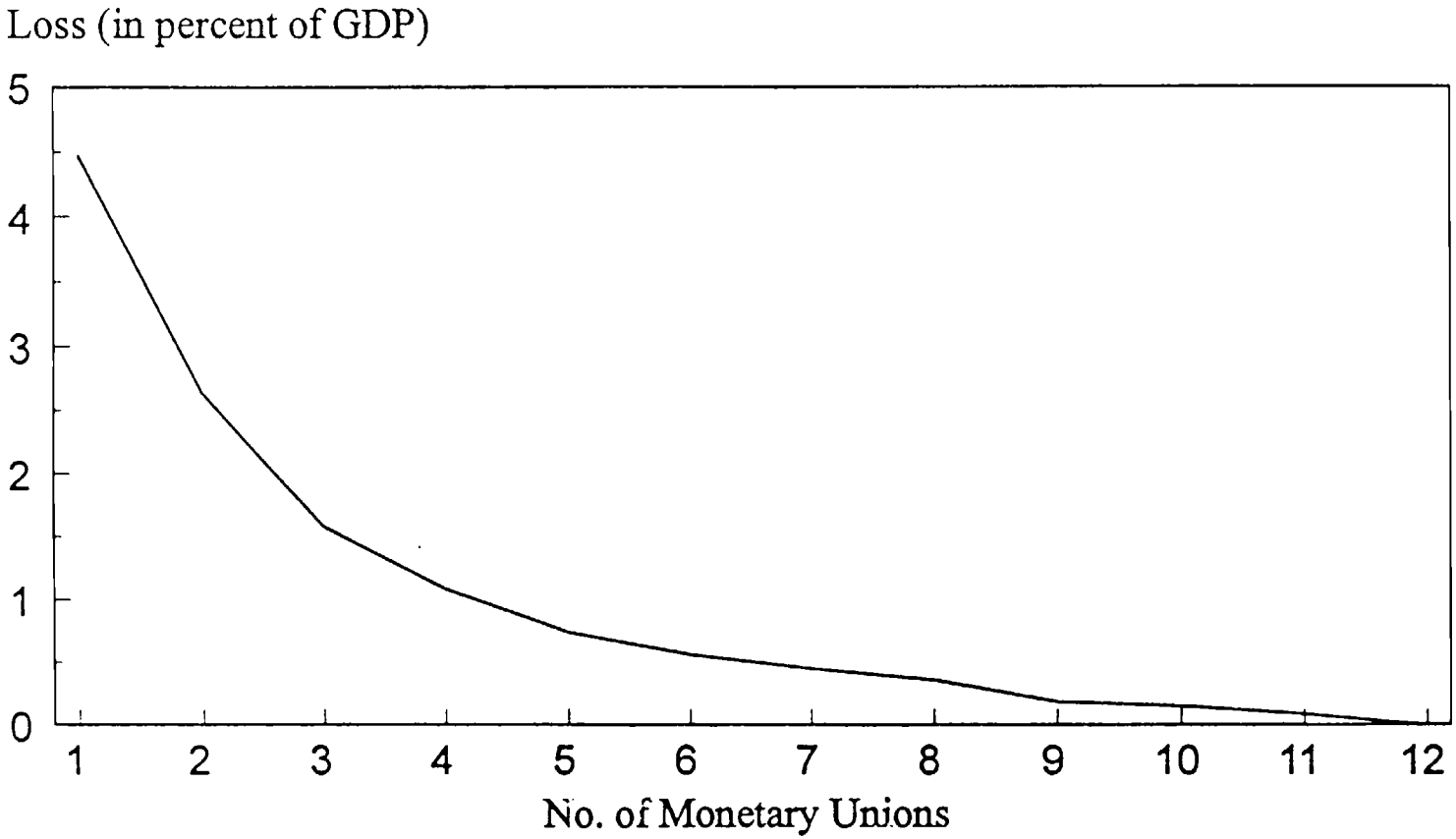
Table 8: Former Soviet Union Successor States

Non-Contiguous				Contiguous			
2 Unions	4 Unions	6 Unions	8 Unions	2 Unions	4 Unions	6 Unions	8 Unions
Armenia	Belarus	Uzbekistan	Armenia	Armenia	Armenia	Kyrgyzistan	Kyrgyzistan
Georgia			Kyrgyzistan	Azerbeijan	Azerbeijan		
Kyrgyzistan	Azerbeijan	Belarus	Russia	Belarus	Belarus	Moldova	Ukraine
Latvia	Georgia			Georgia	Georgia	Ukraine	
Moldova	Lithuania	Ukraine	Ukraine	Latvia	Latvia		Moldova
Russia	Ukraine			Lithuania	Lithuania	Belarus	
		Kyrgyzistan	Latvia	Moldova	Russia		Latvia
Azerbeijan	Armenia	Latvia	Moldova	Russia		Armenia	Lithuania
Belarus	Kyrgyzistan	Moldova	Turkmenistan	Ukraine	Turkmenistan	Georgia	
Lithuania	Latvia	Russia			Uzbekistan	Latvia	Azerbeijan
Turkmenistan	Moldova		Georgia	Kyrgyzistan		Lithuania	
Ukraine	Russia	Armenia		Turkmenistan	Moldova	Russia	Turkmenistan
Uzbekistan	Turkmenistan	Georgia	Azerbeijan	Uzbekistan	Ukraine		Uzbekistan
		Lithuania				Azerbeijan	
	Uzbekistan	Turkmenistan	Uzbekistan		Kyrgyzistan		Armenia
						Turkmenistan	Georgia
		Azerbeijan	Belarus			Uzbekistan	Russia
			Lithuania				Belarus

Not surprisingly, the ruble zone fragments into groups centered around the two largest republics, Ukraine and Russia. Allowing for more unions, it is Ukraine rather than Russia breaking away for a separate currency. Turning to the recent re-integration efforts, the table

[15] The recent agreement between Belarus and Russia suggests that a new ruble zone may rise from the ruble of the old.

Twelve Successor States of the Former Soviet Union



provides no support for the notion that Russia and Belarus constitute an optimal union. Indeed, to the extent that the historical data can be taken seriously, the cost of maintaining a common currency is some 4.5 percent of GDP. Figure 8, plotting the loss against the number of unions, reveals no support for a either a continuation of the ruble zone or for the sometimes proposed system of currency boards [Hanke, Jonung and Schuler (1993)] with non-adjustable pegs, creating a de facto currency area vis a vis outside currencies.

4.6 The World Economy

Finally, we turn to the world at large. As Cooper (1984) notes , while the adoption of a single global currency is unrealistic even in the medium term, it may provide a vision guiding interim steps in improving international monetary arrangements. Moreover, it is of some interest to examine whether the gradually emerging currency blocs — centered on the dollar, the Deutschemark/ECU, and the Yen — can lay a claim to OCA status or are predominantly the result of historical or political considerations.

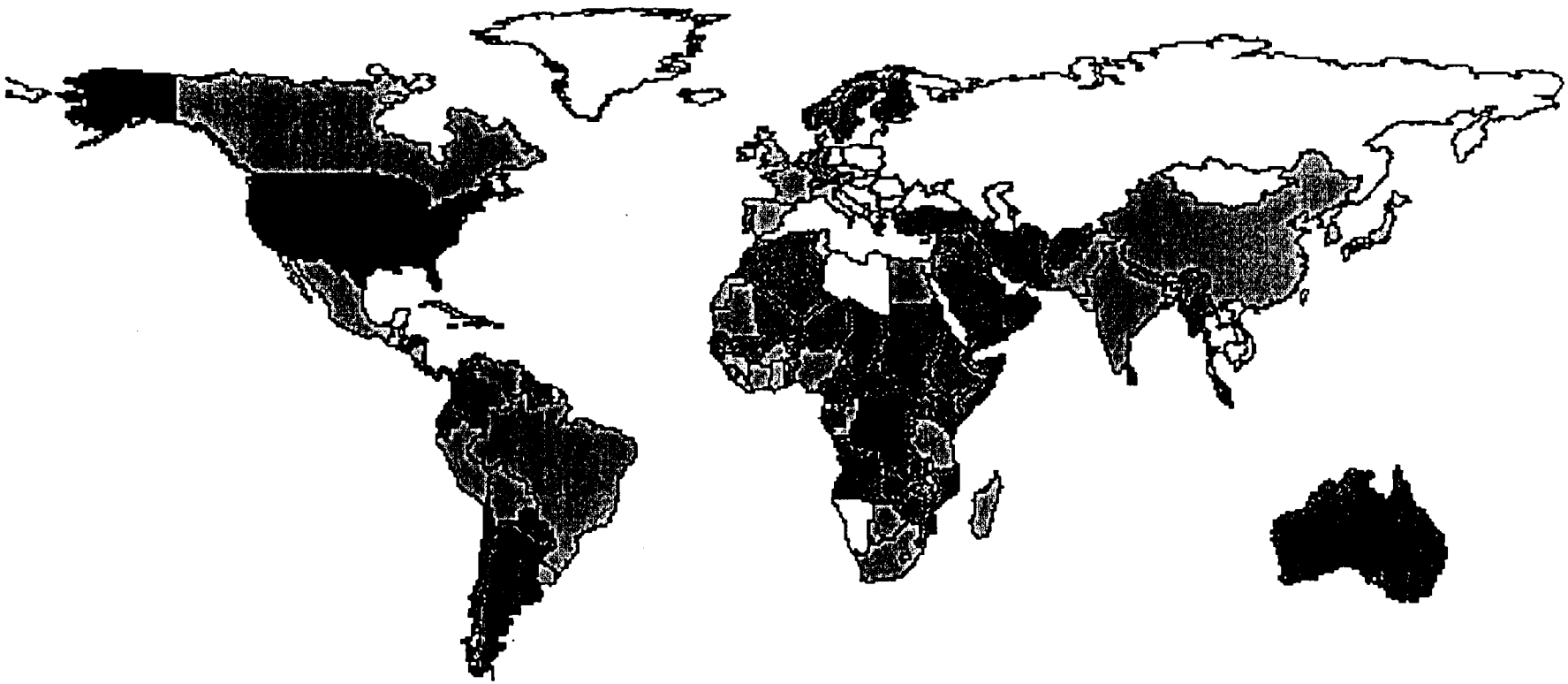
Table 8 reports the results for the non-adjacent world, again based on the Summers and Heston data set. When there are three currencies (figure 8), the United States, Japan, and Germany do indeed have separate currencies, however, the allocation does not correspond to the fashionable three block hypothesis. The dollar "bloc" consists only of the United States. The second block, while including Japan and much of Asia, also comprises Canada, Brazil and most of western Europe and thus cannot be labelled a Yen block. The third group combines central and northern Europe with most of Africa and south west Asia, again a far cry from a true DM block.

5 Conclusions

Most instances of countries sharing their currencies have arisen from a combination of historical accidents and political forces. Yet as recent events in the monetary integration of Western Europe have so dramatically shown, political will may be insufficient to sustain integration efforts when the costs of foregone stabilization policy are too large. Indeed, our results suggest that, had the states of the US not adopted a single currency before the widespread use of stabilizing macroeconomic policy, the costs of forming a monetary union may have proved prohibitive.

Table 7: World Non-Contiguous

2 Unions		5 Unions		10 Unions		20 Unions	
Afghanist.	Liberia	Afghanist.	Ghana	Angola	Algeria	Angola	Algeria
Algeria	Luxembo.	Argentina	Guatemala	Australia	Finland	Burundi	Israel
Angola	Madagascar	Australia	Guyana	Benin	Iran	Guatemala	Nicaragua
Argentina	Malawi	Austria	Iceland	Chad	Lesotho	Iceland	Papua N.G.
Australia	Malaysia	Burki.Faso	Ivory Coa.	Congo	Malaysia	Lesotho	Sweden
Austria	Mali	Cape Verde	Kuwait	Ecuador	Papua N.G.	Luxembo.	Syria
Bangladad.	Malta	Chile	Luxembourg	Gabon	Portugal	Malaysia	Zimbabwe
Barbados	Mauritania	Congo	Mauritania	Gambia	S. Arabia	Mauritania	
Belgium	Mauritius	Costa Rica	Niger	Iceland	Singapore	Mozambique	CAR
Benin	Mexico	Cyprus	Panama	Israel	Sri Lanka	Niger	Congo
Bolivia	Morocco	Egypt	Peru	Jamaica	Switzerla.	Norway	Haiti
Botswana	Mozambique	Gabon	Portugal	Kuwait	Tri.&Tob.	Portugal	India
Brazil	Myammar	Greece	SouthKorea	Luxembourg	Zambia	Somalia	Mauritius
Burki.Faso	N. Zealand	Honduras	Sierra Le.	Malawi		Sudan	Pakistan
Burundi	Nepal	Hong Kong	Somalia	Phillipin.	China	Thailand	Zambia
Cameroon	Netherland	Indonesia	Taiwan	Sudan	Domi. Rep.	Turkey	
Cape Verde	Nicaragua	Iran	Thailand	Sweden	Guatemala		Australia
CAR	Niger	Iraq	Togo	Syria	Guyana	Belgium	Botswana
Chad	Nigeria	Ireland	Tunisia		Honduras	Cameroon	Gabon
Chile	Norway	Israel	Turkey	Cameroon	Liberia	Colombia	Kuwait
China	Pakistan	Jordan	Uruguay	Egypt	Mali	Egypt	Madagascar
Colombia	Panama	Kenya	West Germ.	India	Mauritius	Ethiopia	Togo
Congo	Papua N.G.	Lesotho	Zaire	Nigeria		Guyana	
Costa Rica	Paraguay	Liberia		Norway	Bolivia	Iran	Ghana
Cyprus	Peru	Malaysia	Barbados	Pakistan	Burundi	Kenya	Gui.-Biss.
Denmark	Phillipin.	Mozambique	Botswana	Rwanda	Canada	Panama	Guinea
Domi. Rep.	Portugal	Myammar	Brazil	SouthKorea	Ghana	Sau.Arabia	Indonesia
Ecuador	Rwanda	Nepal	CAR	Spain	Haiti	Suriname	Jordan
Egypt	Sau.Arabia	Norway	China	Togo	Malta	Taiwan	Singapore
El Salvad.	SouthKorea	Papua N.G.	Denmark	U.K.	Mexico	Tunisia	
Ethiopia	Senegal	Phillipin.	Domi. Rep.	Venezuela	Mozambique	Uruguay	Barbados
Fiji	SierraLeo.	Rwanda	Ecuador		Netherla.	WestGerma.	Nigeria
Finland	Singapore	Sau.Arabia	Fiji	Argentina	Senegal		SierraLeo.
France	Somalia	Senegal	France	Bur.Faso	Swaziland	Argentina	Sri Lanka
Gabon	South Afr	Sri Lanka	Gambia	Chile	Tunisia	Benin	Zaire
Gambia	Spain	Sudan	Guin.-Bis.	Cyprus		Chile	
Ghana	Sri Lanka	Swaziland	Haiti	Greece	Afghanist.	Cyprus	Denmark
Greece	Sudan	Sweden	Italy	Guinea	Botswana	Gambia	Jamaica
Guatemala	Suriname	Switzerla.	Japan	Hong Kong	CAR	Greece	Mexico
Guin.-Bis.	Swaziland	Syria	Madagascar	Iraq	El Salvad.	Hong Kong	Netherlan.
Guinea	Sweden	Tri.&Tob.	Malawi	Mauritania	Fiji	Iraq	South Afr.
Guyana	Switzerla.		Malta	Myammar	Indonesia	Ireland	
Haiti	Syria	Burundi	Mexico	Nicaragua	Jordan	Liberia	Bur.Faso
Honduras	Tri.&Tob.	Canada	Morocco	Panama	Madagascar	Senegal	France
HongKong	Taiwan	Guinea	N.Zealand		Niger		Ivory Coa.
Iceland	Tanzania	Jamaica	Netherlan.	Austria	Paraguay	Bolivia	Malawi
India	Thailand	Mali	Nicaragua	Barbados	Somalia	Paraguay	
Indonesia	Togo	Mauritius	Nigeria	Belgium		Peru	Canada
Iran	Tunisia	Suriname	Pakistan	Colombia	Bangladesh	Spain	El Salvad.
Iraq	Turkey	USA	Paraguay	Costa Rica	Brazil	Swaziland	Fiji
Ireland	U.K.		Singapore	Ethiopia	Cape Verde	Tri.&Tob.	Mali
Israel	Uganda	Algeria	South Afr.	Guin.-Bis.	Denmark	U.K.	
Italy	Uruguay	Angola	Tanzania	Ivory Coa.	France	Uganda	Banglades.
Ivory Coa.	Venezuela	Bangladesh	Uganda	Kenya	Ireland	Venezuela	Japan
Jamaica	West-Germ.	Belgium	Venezuela	Morocco	Italy		N. Zealand
Japan	Zaire	Benin	Zambia	N.Zealand	Japan	Afghanist.	
Jordan	Zambia	Bolivia	Zimbabwe	Nepal	Peru	Costa Rica	China
Kenya	Zimbabwe	Cameroon		SierraLeo.	South Afr.	Domin.Rep.	Malta
Kuwait		Colombia	Chad	Taiwan	Suriname	Honduras	
Lesotho	Canada	El Salvad.	India	Tanzania	Uganda	Rwanda	Brazil
cont.	USA	Ethiopia	Spain	Thailand	Uruguay	SouthKorea	Tanzania
		Finland	U.K.	Turkey	Zimbabwe	Switzerla.	
		Cont.		W.Germ.			Cape Verde
				Zaire	USA	Austria	Italy
						Chad	
						Ecuador	Phillipin.
						Finland	
						Morocco	USA
						Myammar	
						Nepal	



Three World non-Contiguous Monetary Unions

But the choice between the two extremes of a single currency or an independent currency for each country is a false one. Rather, regions which are considering the adoption of a common currency should first try to identify optimal members of smaller unions, which could later be linked if the correlation of shocks, or *de facto* factor mobility, become sufficiently high. In this context, it is revealing that a "two-track" Europe would consist of all the EU countries *except* Germany forming one union, and Germany maintaining its separate currency. If the case for monetary integration in Europe (or even the states of the US) is less than compelling, it is even more difficult to make for either the CFA countries or the states of the Former Soviet Union.

In concluding, we raise a number of issues not addressed in the paper. The first of these is to emphasize the "essentially political determination of currency questions" [Goodhart (1993:5)]. The rapid disintegration of the ruble zone, the stability of the US dollar zone and the move towards EMU cannot be wholly understood without explicit consideration of non-economic objectives. Our approach in contrast is strictly limited to determining the optimal *economic* composition of monetary unions. [16] Secondly, we have not addressed the issue of seignorage: joining a monetary union generally entails reduced inflation tax revenues for the higher inflation members. In principle, the algorithm used above can be straightforwardly modified to restrict optimal unions to members with comparable reliance on inflation tax. In general, however, one suspects that the decision for membership in a monetary union is partly motivated by a desire to reduce inflation and hence entails reduced reliance on seignorage. Third, we have not taken account of the transitional costs of moving from one monetary arrangement to another. To the degree that these costs are substantial, as observers have argued to be the case for the dissolution of the former Soviet Union and the former Yugoslavia, they weaken the case for splitting up an existing federal monetary union such as the United States or Canada.[17] Fourthly, we have said little about the credibility effects of joining monetary unions. If a central bank administering an existing independent currency has a poor reputation for avoiding hyper- or high inflations, the gains from enhanced credibility obtainable by joining a low inflation monetary union may outweigh the costs of foregone stabilization. Our estimates in this case should be

[16] Goodhart (1993) provides a fuller treatment of the political issues involved in monetary unification and disintegration.

[17] Goodhart (1993) provides a detailed treatment of the transitional costs of monetary (dis-) integration.

interpreted as the *minimum* creditability gain necessary to justify surrendering national monetary sovereignty.

References

[1] Aizenman, Joshua and Robert Flood (1993); "A Theory of Optimum Currency Areas: Revisited"; *Greek Economic Review.*

[2] Bayoumi, Tamin and Barry Eichengreen (1992); "Shocking Aspects Of European Monetary Integration"; CEPR Discussion Paper No. 643.

[3] Bayoumi, Tamin (1994); "A Formal Model Of Optimum Currency Areas"; IMF Working Paper No. 42.

[4] Bhatia, Rattan (1985); **The West African Monetary Union: An Analytical Review**; IMF Occasional Paper 35.

[5] Bini Smaghi, Lorenzo and Silvia Vori (1993); "Rating the EU as an Optimal Currency Area"; Banca d'Italia Temi di Discussione, No. 187.

[6] Bofinger, Peter (1994); "Is Europe An Optimum Currency Union?"; CEPR Discussion Paper No. 915.

[7] Bougthon, James (1991); "The CFA Franc Zone: Currency Union and Monetary Standard"; IMF Working Paper No. 133.

[8] Bougthon, James (1993); "The Economics Of The CFA Franc Zone"; in Masson and Taylor (1993: 96-110).

[9] Canzoneri, Matthew and Carol Ann Rogers (1990); "Is The European Community An Optimal Currency Area?" *American Economic Review*, 80: 419-33

[10] Casella, Alessandra (1990); "Participation In A Currency Union"; NBER Working Paper No. 3220.

[11] Casella, Alessandra and Jonathan Feinstein (1990); "Public Goods In Trade"; NBER Working Paper No. 3554.

[12] Cooper, Richard (1984) ; "A Monetary System For The Future"; *Foreign Affairs*, Fall, 166-84.

[13] DeGrauwe, Paul and Wim Vanhaverbeke (1991); "Is Europe an Optimum Currency Area?"; CEPR Discussion Paper No. 555.

[14] Devarajan, Shantayanan and Dani Rodrick (1991); "Do The Benefits Of Fixed Exchange Rates Outweigh Their Costs? The Franc Zone In Africa"; NBER Working Paper No. 1991.

[15] Eichengreen, Barry (1990a); "One Money For Europe?"; *Economic Policy*, 10: 117-87.

[16] Eichengreen, Barry (1990b); "Is Europe An Optimum Currency Area?"; CEPR Discussion Paper No. 478.

[17] Eichengreen, Barry (1993); "Labor Markets And European Monetary Unification" In Masson and Taylor (1993: 130-62).

[18] European Union Commission (1990); "One Market, One Money"; *European Economy*, 44.

[19] Feldstein, Martin (1992); "The Case Against EMU"; *The Economist*, June 13th.

[20] Giersch, Herbert (1949); "Economic Union Between Nations And The Location Of Industries"; *Review of Economic Studies*, 87-97.

[21] Goodhart, Charles (1993); "The Political Economy Of Monetary Union"; Paper presented at the Conference celebrating the 50th anniversary of Essays in International Finance, Princeton, April 15-16, 1993.

[22] Graboyes, R.F. (1990); "The EMU: Forerunners and Durability"; *Economic Review*, Federal Reserve Bank of Richmond, July/August, 8-17.

[23] Gros, Daniel, Jean Pisani-Ferry and Andre Sapir (eds.) (1992); **Inter-State Economic Relations In The Former Soviet Union**; CEPS Working Document No. 63.

[24] Gros, Daniel (1993); "Costs And Benefits Of Economic And Monetary Union: An Application To The Former Soviet Union"; in Masson and Taylor (1993: 55-74).

[25] Hanke, S., L. Jonung and K. Schuler (1993); **Russian Currency and Finance: A Currency Board Approach To Reform**; Routledge, London.

[26] Hanson, Ardo (1993); "The Trouble With The Ruble: Monetary Reform In The Former Soviet Union"; in Anders Aslund and Richard Layard (eds.) **Changing The Economic System In Russia**; Pinter Publishers Ltd., London.

[27] Holland, J. (1975); **Adaptation In Natural And Artificial Systems**; University of Michigan Press.

[28] International Monetary Fund (1994); **Financial Relations Among Countries Of The Former Soviet Union**; IMF Economic Reviews, Vol. 1., Washington, D.C.

[29] Ishiyama, Yoshihide (1975); "The Theory of Optimum Currency Areas: A Survey"; *IMF Staff Papers*, 22: 344-383.

[30] Kenen, Peter B. (1969); "The Theory Of Optimum Currency Areas: An Eclectic View"; in Robert Mundell and Alexander Swoboda (eds.) ; **Monetary Problems of the International Economy**, University of Chicago Press.

[31] Koza, J. (1993); **Genetic Programming**; Cambridge, MA.

[32] Krugman, Paul (1993); **Geography and Trade**, MIT Press, Cambridge.

[33] Masson, Paul and Mark Taylor (1993); **Policy Issues In The Operation Of Currency Unions**; University of Cambridge Press.

[34] McKinnon, Ronald (1963); "Optimum Currency Areas" ; *American Economic Review*, 53:4:

[35] Meese, Richard (1990); "Currency Fluctuations In The Post Bretton Woods Era"; *Journal of Economic Perspectives*, 4: 117-131.

[36] Melitz, Jacques (1991); "A Suggested Reformulation of the Theory of Optimal Currency Areas"; CEPR Discussion Paper No. 590.

[37] Mill, John Stuart (1894); **Principles of Political Economy**, Vol. II, New York.

[38] Mundell, Robert A. (1961); "A Theory of Optimum Currency Areas"; *American Economic Review*, 60:4:657-65.

[39] Myrdal, G. (1957); **Economic Theory and Underdeveloped Regions**; London.

[40] Scitovsky, T. (1958); Economic Theory and Western European Integration; Stanford.

[41] Siklos, Pierre (1994); "Varieties of Monetary Reforms"; IMF Working Papers No. 57, May.

[42] Tower, Edward and Thomas Willett (1976); "The Theory of Optimum Currency Areas and Exchange Rate Flexibility"; Princeton University, Special Papers in International Economics, No. 11.

[43] von Hagen, Jürgen (1993); "Monetary Union And Fiscal Union"; in Masson and Taylor (1993: 264)

[44] Wihlborg, C. and T. Willett (1992); "Optimum Currency Areas Revisited"; in C. Wihlborg, N. Fratianni and T.D. Willett (eds.) ; Financial Regulation and Monetary Arrangements After 1992; Elsevier, Amsterdam.

[45] Wolf, Holger (1992); "Economic Disintegration"; in Richard O' Brien (ed.) Finance and the International Economy; Oxford University Press.