Optimal currency areas and customs unions: are they connected?

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Abstract

This paper examines the link between currency unions and customs unions. The size of a bloc of countries practising some form of co-ordination of monetary policy is limited by the incentive to free-ride that formation of the bloc creates. However, when the threat of a trade war is introduced, the stable size of the bloc increases. This suggests that a) large currency areas are more likely to emerge where it combines with a customs union and b) that the stability of both currency area and customs union is closely related, as the threat of tariff penalties can enforce monetary co-operation.

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1 Introduction

The last decade has seen progress in international economic integration in various parts of the world. Formal regional economic arrangements have probably progressed furthest in Europe, with the creation of a customs union in 1956, the common market in 1992 and the prospects of European Monetary Union in 1999. Similar developments can be observed in the Western Hemisphere, with NAFTA and MERCOSUR. Though there are no formal monetary arrangements analogous to the EMS, many of these countries have an important role for the US dollar, and when they peg their currency, they peg to the dollar. In South-East Asia, ASEAN is developing a free-trade area, perhaps related to the influence of the Japanese yen in Asia.

A number of empirical studies (Frankel and Wei (1993a), (1993b)) have investigated the link between trade blocs and currency blocs. The motivation for attempts to strengthen currency links in free-trade areas is the reduction of exchange rate risk, and the resulting encouragement of trade. Based on similar arguments, the literature on the optimal exchange rate peg suggests that greater weight should be attached to currencies of major trading partners.(1)

This paper provides a complementary explanation for the link between trade policy and monetary policy coordination, using a game-theoretic approach. The use of policy instruments may be graduated so that co-operation at the 'lower' level is enforceable by the threat that, were it to fail, 'higher' level instruments would be used non-cooperatively. Co-operation at the 'lower' level is typically co-operation where gains are not very high and, as a result, coordination is difficult to sustain. Co-operation at the 'higher' level comprises areas where gains from co-operation are high and, as a result, the failure of coordination is costly. Basevi *et al* (1990) formalise such a game for two countries in a two-period general equilibrium model typically used in trade policy models. They assume that monetary policy is effective because wages are fixed at a level above the Walrasian equilibrium level, and are rigid downwards, creating unemployment. Domestic money expansion that reduces unemployment will create a positive externality, since it worsens the terms of trade of the home country. The country would like to co-operate in order to internalise the externality. It can enforce this

(1) For a comprehensive survey on the optimal peg literature, see Williamson (1982).

co-operation by means of threatening to impose tariffs on the foreign good. These tariffs hurt the foreign economy but they do not affect the domestic economy under the specific model assumptions chosen by Basevi *et al.*

In what follows, the basic framework of Basevi *et al* is applied to a standard shock-stabilisation game of monetary policy coordination and combined with tariff policy. The size of a 'stable' coalition is analysed in the context of an n country model. It has been shown that the free-rider incentive in monetary policy games can restrict the stable coalition size (see Martin (1995) and Kohler (1996)). In this paper, it is shown that the prospect of a trade war can enlarge the stable coalition size considerably. The actual size of the stable coalition is determined by the feasible – that is, credible – size of the penal tariff.

The paper is structured as follows. Section 2 presents the basic model and the reduced form. The mathematical derivation of the model is in Appendices A.1 and A.2. Section 3 presents a model of coalition formation with a package deal. (Mathematical solutions are in Appendix A.3.) The stable coalition sizes are discussed in Section 3.3; Sections 4.1 and 4.2 discuss possible limits of the model with respect to the dynamics of coalition formation and the credibility of the punishment. (The results of simulations performed for Section 3.3 and 4.1 are presented in detail in Appendix B.) Section 5 concludes.

2 The underlying economy

The individual country's economy is described by a linear and static macroeconomic model and a monetary policy rule, which rests on a quadratic pay-off function. It is consistent with the models in Canzoneri and Henderson (1988), (1991), Persson and Tabellini (1995) and Buiter *et al* (1995). The model of Canzoneri and Henderson (1988) is extended by the inclusion of tariff policy and generalisation to the n country case.

All variables are in natural logarithms, and are expressed in terms of deviations from their values in a zero-disturbance equilibrium, except for τ_{ij}, which is the (*ad valorem*) tariff imposed by country i on good j. For simplicity, the deviation of the money supply (log) from its zero-disturbance value is referred to as 'money supply'. This convention applies to all other variables accordingly. The domestic country's variables are indexed by i, while $j = 1 \ldots n, j \neq i$ denotes the foreign countries' variables. A symmetric model is used, that is structures are identical in all economies, since this allows focus on aspects of the coalition formation process that are not driven by differences among countries but are intrinsic to the process itself.

Each country specialises in the production of one good, but consumes all goods.

Output y_i increases with employment l_i, subject to decreasing returns to scale, and decreases with some (world) productivity disturbance x (independently distributed, with mean 0).

$$y_i = (1 - \alpha) l_i - x \qquad 0 < \alpha < 1 \tag{1}$$

Profit-maximising firms hire labour up to the point at which real wages are equal to the marginal product of labour. The money wage is denoted by w_i, while p_i is the output price:

$$w_i - p_i = -\alpha l_i - x \tag{2}$$

Home wage-setters set w at the beginning of the period so as to fix employment at a full-employment level ($l_i = 0$) if disturbances are zero and expectations are fulfilled. They minimise the expected deviation of actual employment from full employment by setting the nominal wage:

$$w_i = m_i^e \tag{3}$$

where m_i^e is the expected money supply.[2] Actual labour demand might differ because of unexpected disturbances. It is assumed that the wage-setters guarantee that labour demanded is always supplied.

The market equilibrium for money is realised when the money supply satisfies a simple Cambridge equation:

$$m_i = p_i + y_i \tag{4}$$

where m_i is the money supply.

[2] Equations **1**, **2** and **4** give $m = w + l$. Home wage-setters solve the optimisation problem $min_w E[l^2] = min_w E[(m - w)^2]$. This is obviously minimised by setting w equal to m^e. For the time being, we shall set $m_i^e = 0$.

Besides the tariffs, which affect demand for the foreign goods directly, the real exchange rate, z_{ij},[(3)] is the only source of spillovers between countries. Defined as the relative price of the foreign good j, we can write z_{ij} as:

$$z_{ij} = (e_{ij} + p_j - p_i) \tag{5}$$

where e_{ij} is the nominal exchange rate and p_i (p_j) is the own-currency price of home (foreign) country goods. Thus a positive value of z_{ij}[(4)] reflects a real depreciation.

Real aggregate demand for good i is given by:[(5)]

$$\begin{aligned} y_i \;=\; & \underbrace{(1-\beta)\, y_i}_{\substack{\text{domestic}\\ \text{private}\\ \text{demand}}} + \underbrace{\sum_{\substack{j=1\\ j\neq i}}^{n} \frac{\overline{\tau}_{ij}}{1+\overline{\tau}_{ij}} \frac{\beta}{n-1}\, y_i}_{\substack{\text{domestic government}\\ \text{demand}}} + \underbrace{\sum_{\substack{j=1\\ j\neq i}}^{n} \frac{1}{1+\overline{\tau}_{ji}} \frac{\beta}{n-1}\, y_j}_{\substack{\text{foreign private}\\ \text{demand}}} + \underbrace{\sum_{\substack{j=1\\ j\neq i}}^{n} z_{ij}}_{\substack{\text{relative}\\ \text{prices}}} + \\ & \underbrace{\sum_{\substack{j=1\\ j\neq i}}^{n} \eta_1^{ij}\theta_{ij}}_{\substack{\text{effect of}\\ \text{domestic tariffs}}} - \underbrace{\sum_{\substack{j=1\\ j\neq i}}^{n} \eta_2^{ji}\theta_{ji}}_{\substack{\text{effect of}\\ \text{foreign tariffs}}} + \underbrace{\sum_{\substack{j=1\\ j\neq i}}^{n} \sum_{\substack{h=1\\ h\neq i}}^{n} \eta_3^{jh}\theta_{jh}}_{\substack{\text{trade diversion}\\ \text{effect}}} \end{aligned} \tag{6}$$

Since consumers spend a fixed share $1-\beta$ $(0 < \beta < 1)$ of their income on the domestic good (and, hence, $\frac{\beta}{n-1}$ on each foreign good), demand for the domestic good rises with y_j, $j = 1, \ldots, n$. The foreign demands for the domestic good have to be 'deflated' by the respective tariffs, since the consumer price for a good imported from i is $e_{ji}p_i(1+\tau_{ji})$. τ_{ij} denotes the tariff that country i imposes on goods imported from country j, while θ_{ij} is defined as the deviation of $\ln(1+\tau_{ij})$ from its equilibrium value.

The tariff revenues are spent by the government exclusively on domestic goods; these purchases are denoted by the second term of the demand equation.[(6)]

[(3)] z_{ij} denotes the *world* market real exchange rate. Consumers face an 'actual' real exchange rate that includes the tariff mark-up on the price of the foreign good.

[(4)] Note that all variables are deviations from the long-run equilibrium. A positive value means that the variable is above its equilibrium value.

[(5)] The demand functions are derived from a combination of log linearisation and linear approximation of the expenditure functions (see Appendix A.1).

[(6)] A standard assumption in trade policy models is that the tax revenues are

A rise in the relative price z_{ij} of a foreign good shifts world demand from the foreign good to the home good by δ. A rise in domestic tariffs on imports shifts domestic demand towards the own good by η_1^{ij}. Foreign tariffs imposed on the domestic good shift foreign demand away from good i towards their own good by η_2^{ji}. ($\eta_1, \eta_2 > 0$. Note that η_2 enters *negatively* in equation (**6**).)

While η_1 and η_2 represent the effects of a tariff on the two countries that are directly affected, η_3 represents an inverse of the *trade diversion* effect known from the theory of customs unions (see Viner (1950)). A tariff imposed from country i on good j will reduce domestic demand for good j. In a two-country framework, there is only one way to spend the reduced outlay on the foreign good, that is on the domestic good. In a multi-country framework, however, there is the possibility of substituting towards all other goods. This additional effect on countries 'outside' the tariff is denoted by η_3.

Model symmetry and trade balance(7) require that tariffs are zero in the disturbance-free equilibrium, that is, we are in a worldwide free-trade area where no need for policy intervention arises, and that $\eta_1^{ij} = \eta_1$, $\eta_2^{ij} = \eta_2$ and $\eta_3^{ij} = \eta_3$ for all $i \neq j$, that is, the responses to tariff changes are the same for all goods.(8)

Consequently, the goods market equilibrium can be written as:

$$\beta y_i - \frac{\beta}{n-1}\sum_{\substack{j=1\\ j\neq i}}^{n} y_j = \delta \sum_{\substack{j=1\\ j\neq i}}^{n} z_{ij} + \eta_1 \sum_{\substack{j=1\\ j\neq i}}^{n} \theta_{ij} - \eta_2 \sum_{\substack{j=1\\ j\neq i}}^{n} \theta_{ji} + \eta_3 \sum_{\substack{j=1\\ j\neq i}}^{n} \sum_{\substack{h=1\\ h\neq i}}^{n} \theta_{jh} \quad (\mathbf{7})$$

redistributed to the consumers. In our model, this would change only the size of the demand elasticities with respect to tariffs. η_1 and η_2, the tariff effects on the demand for the domestic good, will be smaller under redistribution, since part of the tariff revenues is now spent on foreign goods. The effect on 'third-country' demand, η_3, will be larger for the same reason. Eventually, this will lead to a situation where the damage that the tariff imposes on the domestic economy is larger, while the damage for the foreign economy is smaller. The reason is that, while having the same direct impact on domestic CPI, the exchange rate movement induced by tariffs is not as favourable for the domestic country as in the case considered in the paper here. Hence, though there will still be a tariff that can sustain full co-operation, the tariff punishment is more likely not to be credible in the case of redistribution. We shall discuss the issue of credibility of the punishment in depth below.

(7) The former is a model assumption, the latter results from the model, since we have no capital markets (see Appendix A.1).

(8) For the proof, see Appendix A.2.

The budget constraint requires that the decrease of demand for a foreign good on which a tariff is imposed is matched by an increase in demand for all other goods: $\eta_2 = \eta_1 + (n-2)\eta_3$. Tariffs and real exchange rates are part of prices faced by consumers. Hence, the respective elasticities of the demand functions, η_1, η_2 and δ, can be expressed as functions of each other, which gives: $\delta = \eta_1 + \eta_2 - \frac{\beta}{n-1}$. That is, a rise in the real exchange rate between two goods is comparable to the situation when a bilateral tariff is imposed and the domestic tariff is positive while the foreign tariff is negative (an import subsidy). However, the shift of consumption towards the domestic good is larger when caused by tariffs than by a real exchange rate depreciation, since in the former case – additionally to the substitution effect – the tariff revenues are spent exclusively on the domestic good. (This is denoted by the term $\frac{\beta}{n-1}$.)[9]

The consumer price index q_i is a weighted average of the domestic and the foreign good prices, where all prices are weighted according to expenditure shares.

$$q_i = (1-\beta)p_i + \frac{\beta}{n-1}\sum_{\substack{j=1 \\ j\neq i}}^{n}(e_{ij} + p_j + \theta_{ij}) = p_i + \frac{\beta}{n-1}\sum_{\substack{j=1 \\ j\neq i}}^{n}(z_{ij} + \theta_{ij}) \quad \textbf{(8)}$$

Inflation may be imported via an appreciation of the foreign currency, or equivalently a depreciation of the domestic currency. An increase in domestic tariffs will initially increase the CPI. However, as we shall see below, the tariff will cause a real appreciation of the domestic currency, which exerts an opposite effect on the domestic CPI.

2.1 Policy-makers' objectives

The policy-maker in the home country has access to two policy instruments, m_i, which we identify with money growth, and τ_{ij}, which we identify with the tariff rate imposed on imports from country j. He evaluates the effects of monetary and trade policy according to a loss function over CPI-inflation and employment:

$$L_i = \frac{1}{2}\left(\sigma l_i^2 + q_i^2\right) \quad \textbf{(9)}$$

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[9] For the proof of these propositions, see Appendix A.2.

where σ denotes the relative weight the policy-maker gives to the employment objective.

Monetary policy comes into effect when there is an (unexpected) symmetric productivity disturbance x. Private agents sign nominal wage contracts. The policy-maker knows the realisation of the shock when setting m, but private agents have no information about it. This could reflect either a genuine information advantage or the relative costs of decision-making (monetary policy can be altered at very short notice, whereas wage contracts cannot). This asymmetric information provides the role for stabilisation policies.[10]

2.2 Reduced form of the economy's behaviour

We can reduce equations (**1**) to (**8**) to two equations for each country.[11] They determine the constraints for the policy-maker's optimisation problem. The money supply m_i and the tariffs τ_{ij} are instruments for minimising the loss function.

The reduced forms for l_i, q_i are:

$$l_i = m_i \quad \textbf{(10)}$$

$$q_i = \lambda m_i - \kappa \sum_{\substack{j=1 \\ j\neq i}} m_j + \underbrace{\frac{\beta}{n-1}\left[\left(1-\frac{\eta_1}{\delta}\right)\sum_{\substack{j=1 \\ j\neq i}}^{n}\theta_{ij} + \frac{\eta_2}{\delta}\sum_{\substack{j=1 \\ j\neq i}}^{n}\theta_{ji} - \frac{\eta_3}{\delta}\sum_{\substack{j=1 \\ j\neq i}}^{n}\sum_{\substack{h=1 \\ h\neq i}}^{n}\theta_{jh}\right]}_{\Theta} + x \quad \textbf{(11)}$$

with:[12]

$$\begin{aligned}
\lambda &= \alpha + \frac{\beta^2(1-\alpha)}{\delta(n-1)} && > 0 \\
\kappa &= \frac{\lambda-\alpha}{n-1} && > 0 \\
\delta &= \eta_1 + \eta_2 - \frac{\beta}{n-1} && \\
\eta_3 &= \frac{1}{n-2}(\eta_2 - \eta_1) && \eta_1, \eta_2, \eta_3, \delta > 0 \quad \text{in most cases.}
\end{aligned}$$

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[10] For an extensive discussion of this interpretation, see Persson and Tabellini (1995).
[11] The reduced form is explicitly derived in Appendix A.2.
[12] The proof for the signs of the coefficients can be checked in Appendix A.1 and A.2 for $\eta_1, \eta_2, \eta_3, \delta$, and λ, κ, respectively.

To set the basic policy problem, let us consider a symmetric world productivity disturbance that gives rise to a stabilisation game. Without policy intervention, a negative disturbance ($x > 0$) will have no effect on the countries' employment and CPI increases. Each country's employment is unaffected, because its nominal output is unaffected; a productivity disturbance lowers a country's real output (according to equation (**1**)) and raises the price of its output by equal amounts (according to equation (**4**)). Marginal productivity of labour falls, so firms will keep employment constant only if increasing output prices lower real wages. All CPIs increase, because all output prices rise. There are no changes in real exchange rates, since outputs fall by the same amount in all countries, because we have assumed symmetry, and so trade is still balanced.[13] In short, a negative productivity shock will leave employment unchanged and increase CPI inflation.

Each policy-maker – facing a loss function that increases with the square of employment and CPI deviations – now has an incentive to contract the money supply a little bit in order to lower inflation. The small loss from reducing employment below the full employment level is accepted in exchange for the significant gain from lowering inflation.

Monetary policy Contractionary monetary policy in country i alone produces a deflationary effect through two channels: the reduction of the domestic output price and the export of inflation via the real exchange rate. Domestically, a reduction in the money supply has to be matched by a fall in nominal output (equation (**4**)), which affects both real output and prices (equations (**1**), (**2**)). The fall in output will reduce employment (equation (**1**)), while the fall in prices lowers CPI inflation. The export of inflation follows from the appreciation of the

[13] If we add an international capital market, as in Canzoneri and Henderson (1991) or Kohler (1996), real interest rates would have to change in order to equilibrate the goods markets. The reason is that only part of the income is used for consumption, while the other part of the income is saved. So the fall in output (supply) is not matched by the fall in demand for this good. A rise in real interest rates that reduces consumption further will re-equilibrate the goods markets. Whether in this case nominal interest rates rise or fall depends on the size of two model parameters. When the real interest rate elasticity of goods demand is lower than the income elasticity of savings, nominal interest rates will rise; if it is the other way around, nominal interest rates will fall (see Kohler (1996)). Since the real and the nominal exchange rate do not change, perfect sustitutability on the international capital markets requires that the real interest rates in all countries rise by the same amount.

real exchange rate. The fall in output prices improves the terms of trade, lowers the prices of imports, and thus lowers inflation. Abroad, the price of imports is increased, thus causing inflation. This externality is reflected in the negative coefficient (κ is positive) of foreign monetary policy in equation (**11**). If all policy-makers contract money supplies, they vainly try to reduce their domestic inflation by attempting to appreciate their currencies against each other. The exchange rate in the end remains unchanged, but all policy-makers have contracted too much with respect to their optimal money supply. This could be avoided if countries coordinated, producing a less contractionary monetary policy.[(14)]

Tariff policy Tariff policy affects inflation without affecting employment. Domestically, nominal output is unaffected (equation (**4**) and – with the marginal productivity of labour unchanged – there is no change in employment, real output and the output price (equations (**1**), (**2**)). The relative price faced by consumers of the foreign good has increased through the tariff. Since this shifts domestic demand towards the home good, the domestic currency appreciates and, eventually, real demand for the domestic good remains constant (equation (**7**)). Consequently, imposing tariffs on imports has two contrasting effects on domestic inflation: an anti-inflationary effect ($-\frac{\eta_1}{\delta}$) through the appreciation of the real exchange rate, which makes foreign goods less expensive, and a direct inflationary effect, since tariffs make imported goods more expensive for the consumer. Depending on which effect dominates, we can distinguish three cases: tariff policy reduces domestic inflation ($\frac{\eta_1}{\delta} > 1$); tariff policy affects only the foreign economies ($\frac{\eta_1}{\delta} = 1$); and tariff policy increases domestic inflation ($\frac{\eta_1}{\delta} < 1$). In the first case, countries may want to try to use tariff policy instead of disinflationary monetary policy. They will not have to hurt the domestic economy by creating unemployment through deflationary monetary policy, but can export inflation without domestic costs. However, tariff policy is an unsuitable instrument to fight inflation, since it will lead directly into a trade war when the other countries retaliate and try to shift the real exchange rate back to its 'original'

(14) Canzoneri and Gray (1985) were the first to formalise this type of monetary policy game, which subsequently became the standard argument in favour of international monetary policy coordination. The same type of model was analysed by Canzoneri and Henderson (1988), (1991), and Persson and Tabellini (1995), among others.

value. A world with many tariffs is not desirable, since it increases the losses of all countries, facing higher CPIs, but the same real exchange rates. In the two latter cases, countries are not able to use tariff policy as a 'direct' instrument to fight inflation; however, they may use tariff threats to induce cooperation in the monetary field, since tariffs always hurt the foreign economies by exporting inflation.

Since δ and η_1 can be expressed in terms of the expenditure function, we can trace the three cases back to the properties of the underlying utility function or, more precisely, to the signs of the cross-price effects.(15) Tariff policy reduces inflation when the cross-price effect is negative. This occurs when we have *normal goods* that are *complements*. One typical example arises with Leontieff-type utility functions, where the consumer wants to consume a basket of goods in which the goods (in real terms) have fixed shares. Tariff policy does not affect the domestic economy when there are no cross-price effects;(16) that is, when the consumption of good i does not depend on the price of good j. This is the case when the consumer spends a fixed nominal share of his income on each good. Tariff policy hurts the domestic economy when the cross-price effects are positive. This is the case when goods are *normal goods* and *substitutes*. This case covers all 'standard' utility functions, such as CES or Cobb-Douglas utility functions.

In what follows, analysis is restricted – if not noted otherwise – to the last case, which seems to be the most reasonable representation of consumption behaviour for a country with respect to a whole range of goods. Tariffs will therefore hurt the domestic economy (a little bit) and the foreign economy (even more).

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(15) For a detailed account, see Appendix A.1.2, equation (**A2**).

(16) This case is in some sense the counterpart to the model in Basevi *et al* (1990). In their model, tariffs do not affect the domestic economy, although the cross-price effects are positive. The crucial difference to our model is that Basevi's model targets private utility. The assumption of unproductive government purchases financed through tax revenues leads to a reduction of private utility. This negative effect is counterbalanced by an increase in domestic production and real income, due to the shift of domestic demand towards the own good.

3 Coalition formation with a package deal

The previous section outlined how policy-makers will react to a negative productivity shock if they do not co-operate. Since they impose negative externalities on each other, there is scope for improvement through co-operation. For this reason, the literature on international monetary policy coordination has – starting with the seminal work of Hamada (1976) – argued that coordination is beneficial for all parties involved.[17]

In Kohler (1996), it is argued that countries may prefer forming a coalition to full coordination (using the model of the previous section with monetary policy only). The main result was that coalition formation will stop when it reaches a size of three countries. The reason is that the coalition formation process itself causes positive spillovers for the outsiders: the increased discipline within the coalition reduces the negative externalities the coalition countries create for *all* countries, independent of whether they are 'ins' or 'outs'. Countries will decide whether to join the union or not on the basis of whether it is more beneficial to reduce imported inflation or to be able to export inflation.

Here, the type of 'co-operation deal' the coalition offers is modified. The coalition will offer all members the possibility of coordinating monetary policy together with zero tariffs, whereas the outsiders will face tariffs imposed on their goods in coalition markets. It will be shown that there is always a tariff high enough that the incentive to free-ride on co-operation in monetary policies vanishes, and only a coalition where all countries are members is stable.

3.1 The strategies and the equilibrium

3.1.1 The coalition strategy

A coalition is a subset of countries that optimise a common loss function. The common loss function is a weighted average of the individual countries' loss functions. The relative weights are denoted by

(17) The type of model used here has been first analysed by Canzoneri and Gray (1985).

α_i, with $\sum_{i=1}^{k} \alpha_i = 1$. Since the model structure is symmetric, it is assumed that the individual countries' weights are equal and, hence, the weight of a coalition member (α_i) is equal to $\frac{1}{k}$ for all $i = 1, \ldots, k$.[18] The coalition consists of the countries $i = 1, \ldots k$ and optimises:

$$\mathcal{L} = \sum_{i=1}^{k} \frac{1}{k} L_i$$

The coalition as a whole plays a Nash game in monetary policies against the outsiders. The $n - k$ outsiders play a non-cooperative Nash game against all other countries by minimising their individual loss functions.

Since tariffs hurt the domestic economy, setting any tariff above zero is sub-optimal for the coalition if monetary and tariff policies are considered separately. However, a penal tariff can create an incentive that outweighs the free-riding incentive of monetary policy coordination. The mere *threat* to punish via the trade sector can be sufficient to induce full co-operation. Therefore, it may be in the interest of the coalition to be able to commit to the package deal.

The model is solved by first determining the equilibrium policies for a given coalition size. Tariffs are fixed at a given level and the optimal monetary policies for this tariff are calculated. The stable coalition size for a given penal tariff level is then determined. Different tariff levels will be shown to sustain different stable coalition sizes. The tariff level that can sustain full co-operation will be called the *threshold tariff*.

Roughly speaking, the penalty must be high enough to be effective, but low enough to be credible. The exact meaning of 'credible' has to be understood in the context of the game: within a static game, it means that it pays for the coalition to choose this strategy; within a (infinitely) repeated game, it can be credible through trigger-strategies of the Friedman type; and within an extensive game it has to fulfill the criterion of sub-game-perfection. If the strategy leading to the highest pay-off is not a best response, the coalition has to find a way to exclude the best-response strategy, ie by credibly committing to the penal

[18] Typically, these weights are the outcome of a bargaining process. We shall assume that – because of the symmetric structure of the countries – the bargaining process will lead to symmetric weights. However, we are aware that the weights are not necessarily proportional to country size, as for example Casella (1992) points out, using a model with asymmetric countries.

strategy. For the moment, attention is restricted to a static game, and it is assumed that the coalition offers *only* the package deal but not monetary policy coordination alone. This assumption is later relaxed.

Once a coalition member, a country will have to stick to the coalition policy. However, the decision whether a country wants to join the coalition or not has to be incentive-compatible for each individual country. Consequently, a coalition is called ‘stable’ when no country would like to change its affiliation (‘in’ or ‘out’) unilaterally. The idea behind this is that an equilibrium with a coalition size where the coalition members prefer to join the outs or *vice versa* is not sustainable. A stability concept is adopted from the analysis of cartels in industrial organisation:[19]

$$L_c(k^*, n) < L_{nc}(k^* - 1, n) \quad and \quad L_{nc}(k^*, n) < L_c(k^* + 1, n)$$

The loss function of a non-member is denoted by $L_{nc}(n, k)$. If it joins the coalition, it will have the loss $L_c(n, k + 1)$. If $L_{nc}(n, k)$ is smaller than $L_c(n, k + 1)$, the country has no incentive to join the coalition and the coalition is ‘externally stable’. If on the other hand no member from the coalition has an incentive to leave the coalition, the coalition is ‘internally stable’. If both conditions are fulfilled, the coalition is stable, with size k.

The equilibrium strategies (that is, optimal money supplies) are now discussed for given coalition size and tariff levels.[20]

3.1.2 The equilibrium strategies and losses outside the coalition

In order to solve the outsider's optimisation problem, n_i and q_i are replaced in the loss function by the reduced-form equations. This function is minimised with respect to m_i, subject to given strategies of the other countries. Since there is a symmetric structure in every respect, we can assume that all countries outside the coalition have the

[19] The stability condition used here is based on the one proposed by D'Aspremont *et al* (1983).

[20] The results are derived in Appendix A.3. We shall keep the analysis short, since this part of the solution (except for the tariffs) has been discussed already in Kohler (1996) in depth.

same optimal money supply m^*_{nc}. The money supply of a non-member is then a function of the coalition's money supply:

$$m^*_{nc} = \vartheta\kappa\sum_{j=1}^{k}\overline{m}_{j,c} - \vartheta\Big[\Theta_{nc} + x\Big] \qquad \textbf{(12)}$$

$$\text{with:} \quad \vartheta = \frac{\lambda}{\sigma + \lambda^2 - \lambda\kappa(n-k-1)} > 0$$

where Θ_{nc} is the impact of the tariff structure faced by an outsider. The optimal policy outside the coalition depends positively on coalition policy, ie the money supplies of a non-member and a coalition member are strategic complements. This means that a less contractionary monetary policy of the coalition members triggers a less contractionary response from the non-members (since imported inflation is reduced).

3.1.3 The Nash equilibrium with a coalition

The coalition solves its optimisation problem subject to a given money supply of the non-members. The symmetry assumption $m^*_{j,c} = m^*_c$ is exploited for all $j = 1, \ldots, k$. This gives a coalition member's reaction function that depends on the non-members' money supply. Through equating the reaction functions, we obtain the equilibrium of the Nash game with a coalition as:

$$m^*_c = -\rho\Big[\kappa(n-k)\vartheta\Theta_{nc} + \Theta_c\Big] - \rho\Big[\kappa(n-k)\vartheta + 1\Big]x \qquad \textbf{(13)}$$

$$m^*_{nc} = -\Big[\omega\Theta_{nc} + \kappa\vartheta k\rho\Theta_c\Big] - \Big[\omega + \kappa\vartheta k\rho\Big]x \qquad \textbf{(14)}$$

with:

$$\rho = \frac{\lambda - \kappa(k-1)}{\sigma + (\lambda - \kappa(k-1))(\lambda - \kappa(k-1) - \kappa^2(n-k)\vartheta k)} > 0$$

$$\omega = \kappa^2\vartheta^2 k\rho(n-k) + \vartheta > 0$$

The equilibrium policies in both games are linear functions of the shock x. If the shock is zero, there is no need for a stabilisation game and so the optimal policies are zero ($\Theta_c = \Theta_{nc} = 0$ when there are no tariffs). If the shock is negative, ie $x > 0$, the optimal policy for all countries is a contractionary monetary policy, since ρ and ω are positive.(21)

(21) For the proof, see Appendix A.3.

3.2 The penal tariff structure

One feature of the model is crucial for the result in the game when only monetary policy is available: countries have only *one* instrument for monetary policy available. This does not allow them to impose different externalities on members and non-members. Hence, a free-rider problem occurs, which causes instability for coalitions of a size greater than three. With tariff policy, however, countries have an instrument available that allows them to apply a different tariff policy to 'friends' or 'enemies'. Consequently, they could force countries to join the coalition by threatening them to punish them if they do not co-operate.

In economic terms, the coalition threatens to form a customs union against the outsiders, which will worsen the outsiders' welfare by appreciating the coalition's currencies and so increasing the outsiders' inflation.

In order to determine the effects of the tariff on the coalition and the outsiders, the following assumptions are now made about a reasonable penal tariff structure, and the expressions for Θ_c and Θ_{nc} are evaluated.

- The coalition forms a customs union. This means that all coalition members apply the same tariff to a specific outsider, and that tariffs within the coalition are zero. (The assumption of a customs union does not necessarily imply that the coalition imposes the same tariff on all outsiders. However, since we have symmetric countries outside the coalition, all outsiders face the same tariff from the coalition.)
- Tariffs are only used as means of punishment[22] by the coalition to force the outsiders to co-operate.
- Tariffs will not be used by outsiders to retaliate, since the costs of the retaliation would be much higher (since the outsider has to punish *all* coalition members) than the gains, that is, the damage it imposes on each coalition member. This is true in particular for larger coalitions such as the 'package-upgrade' scenario discussed

[22] Since we focus on the case where tariffs hurt the domestic and the foreign economy, tariffs will never be used 'in the first place', but only as means of punishment or retaliation. Hence, outsiders have no strategic reason to impose tariffs against each other.

below. All tariffs imposed by non-members will therefore be zero.[23]

We can then simplify Θ_c and Θ_{nc}, where θ_c denotes the tariff imposed by the coalition on outsiders. For a coalition member, this gives

$$\Theta_c = \tfrac{\beta}{n-1}\left[1 - \frac{\eta_1}{\delta} - \frac{\eta_3}{\delta}(k-1)\right](n-k)\theta_c$$

and for an outsider

$$\Theta_{nc} = \tfrac{\beta}{n-1}\left[\frac{\eta_2}{\delta} - \frac{\eta_3}{\delta}(n-k-1)\right]k\theta_c = \tfrac{\beta}{n-1}\left[\frac{\eta_1}{\delta} + \frac{\eta_3}{\delta}(k-1)\right]k\theta_c$$

In both cases, a tariff imposed by the coalition has a negative impact on the domestic economy, since it increases Θ[24] and so, according to equation (**11**), increases inflation, whereas it initially leaves employment unaffected. It should be noted, however, that the inflationary impact on the outsiders' economies is increasing with increasing coalition size, while the impact on the coalition economies is decreasing.

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[23] If we allow for retaliation tariffs imposed by non-members on the coalition, that is, $\theta_{nc} > 0$, we can write Θ as:

$$\Theta_c = \tfrac{\beta}{n-1}\left[1 - \frac{\eta_1}{\delta} - \frac{\eta_3}{\delta}(k-1)\right](n-k)\theta_c + \tfrac{\beta}{n-1}\left[\frac{\eta_2}{\delta} - \frac{\eta_3}{\delta}(k-1)\right](n-k)\theta_{nc}$$

for a coalition member, and

$$\Theta_{nc} = \tfrac{\beta}{n-1}\left[\frac{\eta_2}{\delta} - \frac{\eta_3}{\delta}(n-k-1)\right]k\theta_c + \tfrac{\beta}{n-1}\left[1 - \frac{\eta_1}{\delta} - \frac{\eta_3}{\delta}(n-k-1)\right]k\theta_{nc}$$

for an outsider. While the first terms of each equation denote the damages or costs of a punishment tariff imposed by the coalition, the second terms denote the costs or damages of a retaliation tariff imposed by the outsiders. It can be easily checked that the costs of a punishment tariff for the coalition *decrease* with coalition size, while the damage it causes for the outsiders increases. In contrast, the costs of a retaliation tariff θ_{nc} for an outsider *increase* with coalition size, while the damage it creates for the coalition decreases. Hence, punishment tariffs from the coalition are much more effective and credible than retaliation tariffs from the outsiders when we have higher coalition sizes. This justifies our assumption that outsiders do not retaliate, in particular when the coalition is not very small.

[24] η_1 and η_2 are positive, which explains an inflationary impact for outsiders. The impact on coalition members is inflationary, since
$\delta = \eta_1 + \mathcal{F}_j^i + \eta_3(n-2) > \eta_1 + \eta_3(k-1)$ for $k < (n-1)$.

3.3 The stability of coalitions

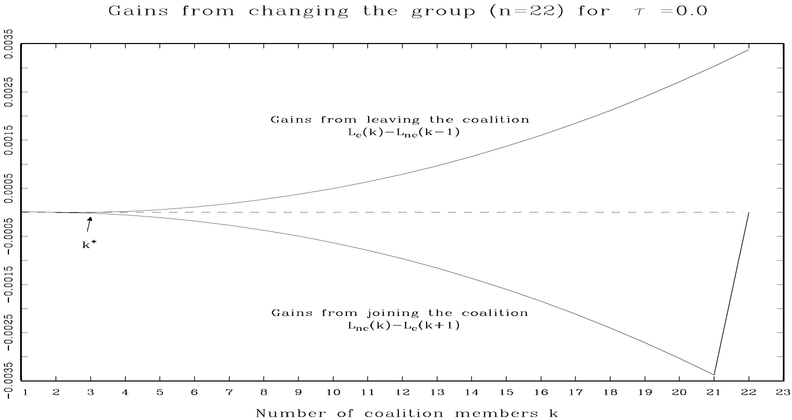
The coefficients ρ and ω in the equilibrium policies are non-linear functions of the model parameters. Hence, it is difficult to analyse how the model parameters, in particular k and τ, affect the equilibrium outcome. This is even more so if we wish to analyse the stability of the coalition. This is determined by differences in the losses, which are quadratic in the optimal policies. One possible approach is to perform numerical simulations with specific values for the model parameters, while varying n, k and τ. Here, only a summary of the most important results is reported; more detailed results and the results of the sensitivity analysis are discussed in Appendix B. We first evaluate how tariffs affect external and internal stability of the coalition, and then determine the stable coalition size.

3.3.1 Tariff impact on external and internal stability

The coalition is externally stable when no outsider wants to join the coalition. It is internally stable when no member of the coalition wants to leave it. The graphs in Figures 1 to 5 below display the stability conditions when there are $n = 22$ countries. When the 'gains from changing the group' are negative for both groups, coalition and outsiders, the coalition is stable. A coalition where all countries are members is externally stable by definition, since there is no outsider left to join – this explains the 'jump' of the graph for external stability from a coalition size of $k = 21$ to $k = 22$.

Figure 1 shows the stability of the coalition when there are no penal tariffs but only monetary policy. The 'gains from leaving the coalition' represent the internal stability condition ($L_c(k) - L_{nc}(k-1) \leq 0$); the 'gains from joining the coalition' are the external stability condition ($L_{nc}(k) - L_c(k+1) \leq 0$). Here, the stable coalition size is three. Above a coalition size of three, it pays for countries to leave the coalition and to profit from the spillovers of coalition discipline while setting an individually optimal response. With increasing coalition size, the potential gains from free-riding become even larger. Below three, on the other hand, it pays to form a coalition with other countries in order to reduce the competitive appreciation of uncoordinated monetary policy. In the monetary policy game with zero tariffs, the outsiders are always

Figure 1: External and internal stability with zero tariffs[(a)]



[(a)] Negative 'gains from changing the group' imply that keeping its affiliation does pay, so that the group is stable. k^* denotes the coalition size that fulfils both stability criteria.

better off than the coalition members, since monetary policies are strategic complements (see Kohler (1996)).

Figures 2 to 5 show how external and internal stability develop for different tariffs. The 'gains from leaving the coalition', which represent internal **in**stability, decrease with increasing coalition size before they start rising again, possibly into the positive area that denotes instability.

Two effects shape this function. The damage that tariffs impose on the outsiders increases with coalition size. On the other hand, the damage that tariffs cause to the coalition economies through inflation of the CPI decreases with coalition size. In combination, these two effects diminish the incentive to leave the coalition as coalition size increases.[(25)] This is even more the case for higher tariffs, since part of the tariff effect is counterbalanced by a more contractionary monetary policy (both optimal monetary policies are negatively dependent on Θ), which increases 'genuine' incentives to coordinate monetary policies.

[(25)] The effect that η_3 has on the economies can be neglected since, especially for 'medium' k, both groups enjoy a similar exposure to 'third party effects': $(n-k-1)k\eta_3$ for the outsiders and $(n-k)(k-1)\eta_3$ for the coalition.

This diminishing effect is moderated by the free-riding incentive of monetary policy coordination, which can be best observed in the game with zero tariffs. Internal stability without tariffs decreases with coalition size because of the reduced coalition externalities, which create a free-riding incentive. When higher coalition sizes are reached, the incentive to free-ride dominates. This explains the U-shape of the internal stability function.

Figure 2: Stability for $\tau = 0.3$

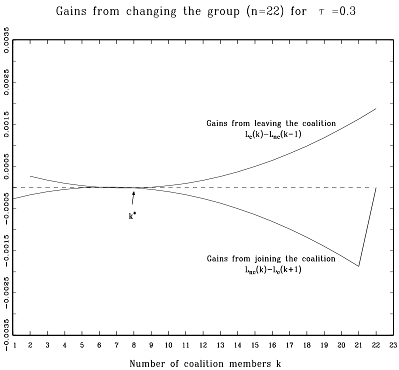


Figure 3: Stability for $\tau = 0.4$

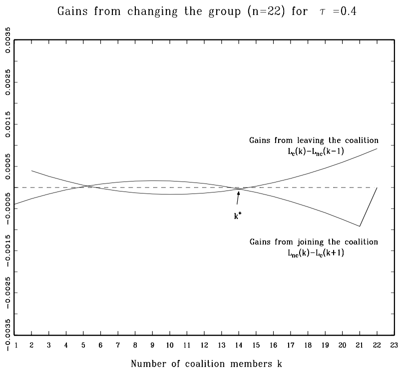


Figure 4: Stability for $\tau = 0.5$

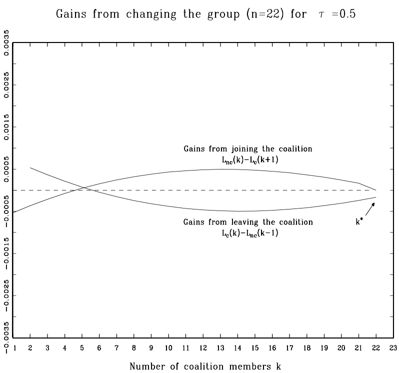
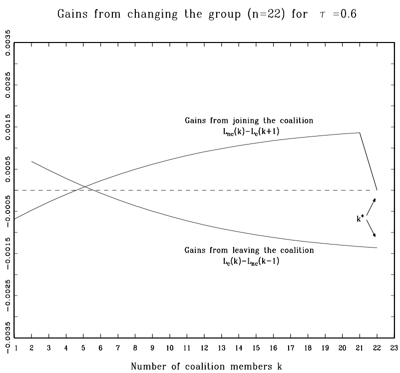


Figure 5: Stability for $\tau = 0.6$

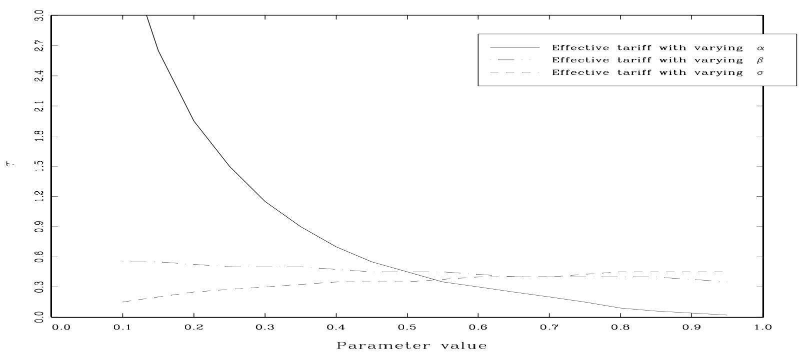


External stability is influenced by the same factors, which now work the other way around. For a low coalition size, incentives to join the coalition are small, since penalties are only imposed through few tariffs, whereas the countries imposing the tariffs have to face a relatively high cost, since they have to punish a large outsider group. This stance, however, is counterbalanced by an intrinsic gain from coordinating monetary policy for low k. With increasing coalition size, it becomes more desirable to join the coalition, because of the increasing tariff burden for outsiders and the decreasing tariff burden inside the coalition. But the free-riding incentives of monetary policy become dominant with higher coalition sizes, leading to a inverse U-shaped form of the external stability function.

3.3.2 Threshold tariff level

An increase in the tariff τ 'shifts' the stability functions: the external stability function is shifted upwards and the internal stability function is shifted downwards. The crucial 'middle' part of the function, where the tariff burden becomes too heavy for the outsiders and the free-riding incentive is not yet large enough for coalition members to leave, is larger the higher the tariff. If this 'middle' part, where the coalition is externally not stable and internally stable, extends over the full coordination point of $k^* = n$, we can reach full coordination as a stable coalition, since at this point the coalition is externally stable, as there are no countries left to contemplate the participation decision.

Figure 6: The threshold tariff level for different α, β and σ



The *threshold* tariff level is the minimum tariff level that sustains full coordination. It has been calculated for various values for the model parameters. The results of the analysis are illustrated in Figure 6 for different values of the parameters α, β and σ.[26] The parameter that influences the threshold tariff level most is (1-α), which denotes the productivity of labour. For $\alpha > 0.5$, the highest threshold tariff level is 0.3, that is, a 30% *ad valorem* tariff on the price of the imported good. Very low values of α require a tariff above two hundred percent. α affects the size of the threshold tariff level much more than any other parameter, because it changes the relative importance of free-riding and penal tariff avoidance. A high α (low labour productivity) implies that the externalities of foreign monetary policy (κ) are low and the effectiveness of domestic monetary policy (λ) is high. In a situation like this, coordinated and non-coordinated monetary policies are not very different, and so gains from being able to free-ride are not very high. Since the impact of the tariff does not depend on α, it is much less profitable to bear a tariff punishment in order simply to exploit the gains from free-riding if α is low.

Though the influence of the other parameters is much less significant, the threshold tariff level decreases with increasing β, η_1 and η_2. A higher propensity to import and a higher tariff elasticity of demand increase the impact of the tariff punishment Θ_{nc}, and so act as if the tariff were higher.

The threshold tariff level increases, however, with the number of the countries n. The reason is that an increase in n reduces Θ_{nc}, the measure of the damage caused by the tariffs for the outsider, and so a higher tariff is necessary for the punishment to be effective.

The threshold tariff increases, too, with σ, the weight of the employment target in the loss function. Since the tariff damages the outsider's economy through inflation, the tariff punishment is much more effective when inflation has a relatively high priority, that is for a low σ. Only when priority shifts to the full-employment target, that is, σ increases, will the inflationary damage a tariff causes become less important. Then only a high penalty will create enough inflation for countries to try to avoid the tariff punishment.

---

[26] We vary only one parameter at a time, while the other parameters take their 'standard values', that is, $\alpha = \beta = 0.5$ and $\sigma = 1$. The detailed results of this analysis (including the results for the parameters η_1 and η_2) and the results of the multivariate analysis are given in Appendix B.

4 Dynamic aspects of the package deal

Up to now, the focus has been on static aspects of the stability of the coalition. The idea is that a given coalition is not sustainable if it is not stable, in the sense that it must be individually optimal for a country to be a coalition member. It has been assumed that the coalition does not offer coordination in a single field but a package deal.

In the following two sections, two different aspects of the 'stable coalition' that are more 'dynamic' are discussed. They deal with the *formation* of the coalition and the credibility of the package deal.

4.1 The process of coalition formation

It has been pointed out that there is always a tariff level high enough that it can sustain full coordination as the stable coalition. However, it is worth considering in more detail the coalition *formation* process, since there may be a problem in 'getting the coalition off the ground'.

As can be seen in Figures 1 to 5, for a very low coalition size (below four or five members), the coalition is internally instable, but externally stable. That is, no country wants to join the coalition, but coalition members want to leave it. This situation changes, however, when the coalition has a larger size: outsiders then want to join the coalition and insiders do not want to leave it. Now consider a coalition *formation* process where one country enters after the other. There may be problems if the group of 'founding members' is too small, since then it would not be able to reach the 'critical size'.

There are two possible ways out of this dilemma. First, the model may be more appropriate for analysis of a 'package upgrade' between existing customs union members than for analysis of coalition formation starting with two members. The game considered so far is *not* intrinsically dynamic. A game that explicitly deals with the formation of the coalition would have to take other dynamic features of monetary policy games, such as expectation formation of the private sector over time, into consideration. The theory of repeated games, which increases the sustainability of co-ordination, would have to be applied. All these aspects are neglected here and, therefore, the model is probably less suitable to explain the dynamic process of coalition *formation*.

However, if we start from a pre-existing trade bloc, this could easily exceed the 'founding size' of five countries. Above this size, the increase is guaranteed: there are negative gains from leaving the coalition, but positive ones from joining it. Hence, the model may serve as a potential application where a 'package upgrade' from a trade block to a currency block is involved. In this light, there is an alternative interpretation of the 'Fortress Europe' idea. Typically, 'Fortress Europe' denotes the establishment or increase of external barriers of an internal European economic policy bloc. This creation of barriers can be considered to be the result of the efforts of all members to keep their existing national protection. Here, there is another, complementary explanation: threats of outside tariffs could be used to sustain policy co-operation for insiders.

Another feature worth noting could provide a second solution to the 'starting problem'. For higher tariffs ($\tau \geq 0.5$) and more countries ($n \geq 9$) particularly, losses inside the coalition are lower than outside the coalition. This can provide a motivation for countries to go ahead and join the coalition early. They may want to belong to the insiders, in case the tariff punishments are actually imposed on outsiders. This incentive may help to reach the critical initial size of the coalition.

4.2 The credibility of punishment in an extensive game

The question of the credibility of the tariff penalty has been excluded, by assuming that the coalition will only have the choice of adopting the package deal, but not either of the two policies separately. This assumption is justified, in that the coalition knows that with monetary policy alone it can not sustain a coalition with more than three countries. Therefore, it would like to be able to commit to the 'package deal', particularly since it is possible to sustain full coordination, and so tariffs are a threat not actually imposed. It could be asked, however, what happens if the coalition cannot commit credibly, for instance on institutional grounds.

A chain store paradox In order to answer this question, it may be reasonable to split the game into a two-stage game, as in Basevi *et al* (1990). In the first stage, monetary policy is conducted and the coalition is decided upon. In the second stage, the outsiders are punished by tariffs imposed by the coalition.

The extensive game has the structure of the 'chain store paradox' discussed in Selten (1978).(27) Like the incumbent in Selten's model, the coalition would prefer to credibly commit to the threat of tariff punishments. However, once the coalition is formed, it is not optimal to carry out the punishment, since it would hurt the coalition as well. If we were to select strictly sub-game perfect equilibria only, the coalition's 'rational' choice would be not to impose any tariff punishments, and the outsiders would not join the coalition beyond size three.

Selten argues, however, that sub-game perfection does not select the intuitively most plausible solution for such a game. Intuitively, one would expect that the coalition will be willing to carry out the punishments the first times they become necessary, in order to build up a reputation to be 'tough', and so to avoid the situation where other countries do not join the coalition. Only if the potential gains from maintaining the reputation are lower than the costs of tariff punishments would the coalition not try to build up a reputation.

Numerical analysis has been performed in order to evaluate whether the costs of punishment exceed the potential gains through reputation. The potential gains are determined by the difference of the losses between the actual coalition size and a coalition of three countries. The results of the analysis are summarised in Table A.(28) We have determined the (maximum) number of outsiders that can be punished with the threshold tariff. This implies a minimum coalition size necessary so that punishment of outsiders pays off. Even though the punishment hurts

(27) In Selten's model, a chain store operates in N markets, in each of which there is a prospective entrant. In case of entry of the competitor, the incumbent can either fight or accommodate. The entrant's profit is positive if the incumbent accommodates, and negative if he fights. The incumbent incurs negative profits if he fights, positive profits if he accommodates, and the highest profits if the competitors stay out. Decisions are made sequentially. In the unique sub-game perfect equilibrium, all potential competitors enter and the chain store behaves passively in all markets. However, intuition suggests that the chain store should act aggressively towards early entrants in order to deter later entrants: it should try to acquire a reputation for being aggressive.

(28) The details of the analysis are given in Appendix B.

the coalition countries, they are still better off than without tariff threats (with a coalition of three, that is) in these cases.

Table A: Punishment of outsiders

Number of countries n =	3	4	5	6	7	8	9	10
Max. number of outsiders	0	0	0	2	3	4	5	6
Min. coalition size	(3)	(3)	(3)	4	4	4	4	4

The analysis shows that if there are six countries, it pays to punish one or two outsiders. If there are seven (or more) countries, even three outsiders (or more) can be punished if this leads to a coalition comprising the remaining countries. That is one more country than the stable coalition when there are no tariffs. Hence, the gains from having one more country in the coalition outweigh the losses of punishing all the remaining countries.(29) Each country that would like to leave the coalition will be punished, since this ensures that the 'necessary' four or five countries remain in the coalition. Therefore, no country will want to stay out.

This solution, however, is not formal, since building up a reputation requires a model of sequential entrance. The following paragraph outlines such a formal model; the analysis is left for later work.

Solutions to the chain store paradox Kreps and Wilson (1982) and Milgrom and Roberts (1982) have suggested a resolution to the paradox,(30) based on a model of incomplete information on the outsider's part regarding the 'type' of the coalition. It is assumed that the outsider does not know which 'type' the coalition is, a 'tough' type

(29) These results do not vary with the parameter values (see Appendix B), though they have been tested only up to a total number of ten countries. For more countries, there is probably a limit to the size of the fringe.

(30) The model that they suggest is modified in that the incumbent can now be either weak or strong. If he is strong, he 'enjoys' fighting, since it is his dominant strategy. If he is weak, fighting is costly and can be worthwhile only if it raises profits in another market through building up a reputation for being 'strong'. Only the incumbent knows whether he is 'strong' or 'weak'. The sub-game perfect equilibrium of this game has the following features: in the first markets, entry does not occur. If a firm would enter by mistake, it would be fought by both types. Because the number of markets shrink over time, concerns about reputation become smaller. This encourages entrants to enter. This equilibrium requires that the probability of being strong is not too small.

which punishes, or a 'soft' type which accommodates if challenged. The tough type will always punish, since it is his dominant strategy, whereas the soft type will only punish in order to build up a reputation of being tough. If the probability that the coalition is tough is high enough, no outsider will initially dare to stay out. Only after several countries have joined the coalition will some countries try to stay outside and accept the risk of being punished.

In order to formalise such a model, however, one has to justify incomplete information and different types of pay-off functions for the coalition, one of which has to have a dominant strategy of imposing tariffs on outsiders. An example of the latter is that there may be a different loss function for the coalition, resulting from further gains from the imposition of tariffs. One could draw in this context on the trade policy literature, where the existence of tariffs is explained either by the existence of increasing returns to scale(31) or by lobbying from industries that seek protection.(32) Additionally, it is necessary to introduce some degree of incomplete information on the side of the outsiders.

Extending the game into a game of sequential entrance, that is, giving it a time dimension, opens up different solution concepts based on repeated games. In infinitely repeated games, it is easier to sustain co-operative outcomes since future losses from playing non-cooperatively instead of co-operation are taken into account. Then we would probably get different results even in the pure monetary policy co-operation game. Additionally, adding a time dimension would require an explicitly dynamic model, which would deal with such issues as those of credibility of the monetary authority towards the private sector. We leave this for future research.

5 Conclusion

In the real world, 'package deals' can be observed more often than simple coordination in specific policy fields. This paper provides a formal model that tries to explain why this comes about, and what the advantages are of a package deal *vis-à-vis* single policy coordination.

(31) See eg Krugman (1979) for the seminal work in this area, or Krugman (1990) for a comprehensive survey.
(32) See Rodrik (1995) for a survey of this literature.

In order to evaluate 'package deal' questions, the game of Basevi *et al* (1990) has been applied to a standard model of monetary policy coordination and extended to more than two countries. This covers the issue of a customs union that wants to extend coordination to the monetary field. The customs union can be exploited strategically to influence the formation of a currency bloc.

Monetary policy coordination alone provides small incentives to form larger blocs, since the free-riding incentive dominates the gains from co-operation above the three-country case. Tariff policy threats, however, add an incentive that makes full coordination sustainable if the tariff level is high enough. The most important difference between the two policy instruments is that monetary policy does not allow the policy-maker to apply a different policy to co-operators and to defectors, whereas tariff policy allows discrimination between them.

There are problems in analysing trade policy in models that are mainly used to explain monetary policy coordination. In these models, trade policy will generally not be profitable for either economy. Consequently, the penal tariff may face problems of credibility, particularly if the threshold tariff is high. Then we have either to lower the 'damage' and take the risk that full coordination cannot be sustained, or we have to modify the model in line with the reputation models of Kreps and Wilson (1982) and Milgrom and Roberts (1982). In this case too, full co-operation may not be sustainable.

Appendix A
Mathematical appendix

A.1 Deriving the demand equation

A.1.1 Linear approximation of the demand function

The real aggregate demand function for good i is derived from a combination of loglinearisation and linear approximation of the expenditure functions, following the procedure proposed by Canzoneri and Henderson (1988), page 100.

Aggregate demand for good i is the sum of domestic private demand, foreign private demand and domestic public demand. The latter is equal to the domestic tariff revenues that the government spends exclusively on the domestic good.

f^{ij} denotes the expenditure function of country i on good j. All capital letter variables denote the respective variables in levels. Nominal expenditure is dependent on income (which equals nominal output in our model if money markets are in equilibrium) and the respective domestic prices of all goods. Hence, nominal expenditures (in domestic currency) are:

$f^{ii}[P_i Y_i, \{E_{ih} P_h (1+\tau_{ih})\}_{h\,=\,1\ldots n}]$	domestic private outlays for good i
$f^{ij}[P_i Y_i, \{E_{ih} P_h (1+\tau_{ih})\}_{h\,=\,1\ldots n}]$	domestic private outlays for good j
$f^{ji}[P_j Y_j, \{E_{jh} P_h (1+\tau_{jh})\}_{h\,=\,1\ldots n}]$	foreign private outlays for good i

All real expenses are in terms of units of good i. The price of the domestic good abroad is $E_{ji} P_i (1+\tau_{ji}) = \frac{P_i(1+\tau_{ji})}{E_{ij}}$; hence, the foreign demands for good i have to be multiplied by $\frac{E_{ij}}{P_i(1+\tau_{ji})}$. Bearing in mind that expenditure functions are linear-homogenous in prices (and hence, in real exchange rates and in *ad valorem* tariffs $(1+\tau)$), the real aggregate demand for good i in levels is:

$$Y_i \quad = \quad f^{ii}[Y_i, \{Z_{ih}(1+\tau_{ih})\}_h] + \sum_{\substack{j=1 \\ j\neq i}}^{n} \frac{\tau_{ij}}{1+\tau_{ij}} f^{ij}[\cdot] +$$

$$\sum_{\substack{j=1\\j\neq i}}^{n} \frac{1}{1+\tau_{ji}} f^{ji}[Z_{ij}Y_j, \{Z_{ih}(1+\tau_{jh})\}_h] \qquad \mathbf{(A1)}$$

where $Z_{ij} = E_{ij}\frac{P_j}{P_i}$ denotes the real exchange rate between good i and good j.

As in Canzoneri and Henderson (1988), taking logarithms, linearising around the disturbance-free equilibrium values $\ln \overline{Y}_i$, etc, and replacing $y = \ln Y_i - \ln \overline{Y}_i$, $z_{ij} = \ln Z_{ij} - \ln \overline{Z}_{ij}$ and $\theta_{ij} = \ln(1+\tau_{ij}) - \ln(1+\overline{\tau}_{ij})$ gives:

$$y_i = \left[f_0^{ii} + \sum_{\substack{j=1\\j\neq i}}^{n} \frac{\overline{\tau}_{ij}}{1+\overline{\tau}_{ij}} f_0^{ij}\right] y_i + \sum_{\substack{j=1\\j\neq i}}^{n} \left[\frac{1}{1+\overline{\tau}_{ji}} f_0^{ji}\right] y_j +$$

$$\sum_{\substack{j=1\\j\neq i}}^{n} \underbrace{\left[f_j^{ii}(1+\overline{\tau}_{ij}) + \frac{1}{1+\overline{\tau}_{ji}} f_0^{ji}\overline{Y}_j + \sum_{\substack{h=1\\h\neq i}}^{n} \frac{\overline{\tau}_{ih}(1+\overline{\tau}_{ij})}{1+\overline{\tau}_{ih}} f_j^{ih} + \sum_{\substack{h=1\\h\neq i}}^{n} \frac{1+\overline{\tau}_{hj}}{1+\overline{\tau}_{hj}} f_j^{hi}\right] \frac{\overline{Z}_{ij}}{\overline{Y}_i}}_{\delta^{ij}} z_{ij} +$$

$$\sum_{\substack{j=1\\j\neq i}}^{n} \underbrace{\left[f_j^{ii}\overline{Z}_{ij} + \sum_{\substack{h=1\\h\neq i}}^{n} \frac{\overline{\tau}_{ih}}{1+\overline{\tau}_{ih}} f_j^{ih}\overline{Z}_{ij} + \frac{1}{(1+\overline{\tau}_{ij})^2}\overline{f}^{ij}\right] \frac{1+\overline{\tau}_{ij}}{\overline{Y}_i}}_{\eta_1^{ij}} \theta_{ij} -$$

$$\sum_{\substack{j=1\\j\neq i}}^{n} \underbrace{\left[\frac{1}{(1+\overline{\tau}_{ji})^2}\overline{f}^{ji} - \frac{1}{1+\overline{\tau}_{ji}} f_i^{ji}\overline{Z}_{ii}\right] \frac{1+\overline{\tau}_{ji}}{\overline{Y}_i}}_{\eta_2^{ji}} \theta_{ji} + \sum_{\substack{j=1\\j\neq i}}^{n}\sum_{\substack{h=1\\h\neq i}}^{n} \underbrace{\left[\frac{1}{1+\overline{\tau}_{ji}} f_h^{ji}\overline{Z}_{ih}\right] \frac{1+\overline{\tau}_{jh}}{\overline{Y}_i}}_{\eta_3^{jh}} \theta_{jh}$$

where the subscripts denote partial derivatives with respect to the $h-1$th argument, that is eg f_0^{ji} denotes the derivative of f^{ji} with respect to the real income of country j, whereas f_h^{ji} denotes the derivative of f^{ji} with respect to the domestic (in country j that is) real price of good h.

Taking into account that the budget constraint requires that $f_0^{ii} + \sum_{\substack{j=1\\j\neq i}}^{n} f_0^{ij} = 1$ and $f_h^{ii} + \sum_{\substack{j=1\\j\neq i}}^{n} f_h^{ij} = 0$, we can rewrite the demand for good i:

$$y_i \quad = \quad \left[1 - \sum_{\substack{j=1\\j\neq i}}^{n} \frac{1}{1+\overline{\tau}_{ij}d} f_0^{ij}\right] y_i + \sum_{\substack{j=1\\j\neq i}}^{n} \left[\frac{1}{1+\overline{\tau}_{ji}} f_1^{ji}\right] y_j + \sum_{\substack{j=1\\j\neq i}}^{n} \delta^{ij} z_{ij} +$$

$$\sum_{\substack{j=1\\j\neq i}}^{n} \eta_1^{ij}\theta_{ij} - \sum_{\substack{j=1\\j\neq i}}^{n} \eta_2^{ji}\theta_{ji} + \sum_{\substack{j=1\\j\neq i}}^{n}\sum_{\substack{h=1\\h\neq i}}^{n} \eta_3^{jh}\theta_{jh}$$

Similarly, the real demand for good k while i is the *numéraire* good can be derived:

$$y_k = \left[1 - \sum_{\substack{j=1\\j\neq k}}^{n} \tfrac{1}{1+\overline{\tau}_{kj}} f_0^{kj}\right] y_k + \sum_{\substack{j=1\\j\neq k}}^{n} \left[\tfrac{1}{1+\overline{\tau}_{jk}} f_0^{jk}\right] y_j + \sum_{\substack{j=1\\j\neq k}}^{n} \delta^{kj} z_{ij} +$$
$$\left[\delta^{ik} - \sum_{\substack{j=1\\j\neq k}}^{n} \tfrac{1}{1+\overline{\tau}_{kj}} f_0^{kj}\right] z_{ik} + \sum_{\substack{j=1\\j\neq k}}^{n} \eta_1^{kj}\ \theta_{kj} - \sum_{\substack{j=1\\j\neq k}}^{n} \eta_2^{jk}\ \theta_{jk} + \sum_{\substack{j=1\\j\neq k}}^{n}\sum_{\substack{h=1\\h\neq k}}^{n} \eta_3^{jh}\ \theta_{jh}$$

A.1.2 Restrictions on the elasticities

In this paragraph, we derive the restrictions that three model features (Walras' law, balanced trade, symmetric countries) impose on the expenditure functions and, hence, on the parameters of the demand functions. Whereas the first two conditions must hold, since we are in a general equilibrium framework, the latter is an assumption. Walras' law must hold with equality when the budget constraints hold with equality, and trade must always be balanced since we have no capital markets. This imposes restrictions on the properties of the expenditure functions and, hence, on the elasticities η_1, η_2, η_3 and δ.

Walras' law Walras' law requires that the n goods demands are linear-dependent. Summing up all demand equations yields an identity for all variable values only if

$$\eta_2^{ij} = \eta_1^{ij} + (n-2)\eta_3^{ij}$$

This condition describes the redistribution of domestic outlay following a decrease in demand for good j due to a tariff imposed on this good. The outlay reduction for good j is distributed to good i according to the elasticity η_1 and, in equal parts since we have symmetric expenditure functions, to the remaining $n-2$ goods.

Trade balance Trade must be always balanced, since we have no capital markets. Substituting the budget constraint $Y_i = f^{ii}[\cdot] + \sum_{\substack{j=1 \\ j\neq i}}^{n} f^{ij}[\cdot]$ into the goods demand (**A1**) gives the trade balance:

$$\sum_{\substack{j=1 \\ j\neq i}}^{n} \tfrac{1}{1+\tau_{ij}} f^{ij}[\cdot] = \sum_{\substack{j=1 \\ j\neq i}}^{n} \tfrac{1}{1+\tau_{ji}} f^{ji}[\cdot]$$

Hence, the trade-balance restriction is ensured when the budget constraints are fulfilled and goods markets are cleared.

In the long-run equilibrium – with natural rates of output being the same in all countries and an equilibrium real exchange rate of unity – bilateral tariffs must be equal. Both monetary and tariff policy would shift the economy away from the disturbance-free equilibrium where the loss function takes its minimum value. Consequently, the Pareto-efficient tariff structure in the long-run equilibrium is **zero** tariffs, since tariffs would only increase the CPI but not affect the real exchange rate, because all bilateral tariffs have to be equal. That is,

$$\overline{\tau}_{ij} = \overline{\tau}_{ji} \quad \forall j, i$$

Using zero-equilibrium tariffs and the budget constraints, while equilibrium real exchange rates are unity and natural rates of output are $\overline{Y}$, we can write:

$$\begin{aligned}
\eta_1^{ij} &= \left[f_j^{ii} + \overline{f}^{ij}\right]\tfrac{1}{\overline{Y}} \\
\eta_2^{ji} &= \left[\overline{f}^{ji} - f_i^{ji}\right]\tfrac{1}{\overline{Y}} = \left[f_0^{ji}\overline{Y} + \sum_{\substack{h=1 \\ h\neq i}}^{n} f_h^{ji}\right]\tfrac{1}{\overline{Y}} \qquad (33) \\
\eta_3^{jh} &= \left[f_h^{ji}\right]\tfrac{1}{\overline{Y}} \\
\delta^{ij} &= \left[\sum_{\substack{h=1 \\ h\neq i}}^{n} f_j^{hi} - \sum_{\substack{h=1 \\ h\neq i}}^{n} f_j^{ih} + \overline{f}_0^{ji}\overline{Y}\right]\tfrac{1}{\overline{Y}} = \eta_1^{ij} + \sum_{\substack{h=1 \\ h\neq i}}^{n} f_j^{hi}\tfrac{1}{\overline{Y}}
\end{aligned}$$

(33) Expenditure functions are always linear-homogenous in prices, and in our model they are linear-homogenous in the income as well. Then the Euler theorem is applicable: $f^{ji} = f_0^{ji}\overline{Z}_{ij}\overline{Y}_j + \sum_{h=1}^{n} f_h^{ji}\overline{Z}_{ih}$. This gives the alternative expression for η_2^{ji}.

Model symmetry Model symmetry requires that the partial derivatives of the expenditure functions across countries and across goods are symmetric. This includes:

- The shares of additional income that are spent on domestic (foreign) goods are equal across countries: $\mathcal{F}_0^i := f_0^{ii} = f_0^{jj}$ *and* $\mathcal{F}_0^j := f_0^{ij} = f_0^{ji} \quad \forall j \neq i$
- The own (real) price effects of domestic (foreign) goods are equal across countries: $\mathcal{F}_i^i := f_i^{ii} = f_j^{jj}$ *and* $\mathcal{F}_j^j := f_i^{ji} = f_j^{ij} \quad \forall j \neq i$
- The cross (real) price effects of domestic (foreign) goods are equal across countries and goods: $\mathcal{F}_j^i := f_j^{ii} = f_i^{jj} =^{(34)} f_i^{ij} = f_j^{ji}$ *and* $\mathcal{F}_h^j := f_h^{ij} = f_j^{ih} = f_h^{ji} \quad \forall j \neq i$

With these conditions, elasticities do not differ across goods and, hence, we can drop the superscripts of δ, η_1, η_2 and η_3. Furthermore, we can now express δ as a function of η_1 and η_2, that is, $\delta = \eta_1 + \eta_2 - \frac{\beta}{n-1}$.

With the model symmetry, we can rewrite the elasticities:

$$\begin{aligned}
\eta_1 &= \Big[\mathcal{F}_j^i + \overline{f}^{ij}\Big]\frac{1}{\overline{Y}} = \Big[-(n-2)\mathcal{F}_h^j - \mathcal{F}_j^j + \overline{f}^{ij}\Big]\frac{1}{\overline{Y}} \\
\eta_2 &= \Big[-\mathcal{F}_j^j + \overline{f}^{ji}\Big]\frac{1}{\overline{Y}} = \Big[(n-2)\mathcal{F}_h^j + \mathcal{F}_j^i\Big]\frac{1}{\overline{Y}} + \mathcal{F}_0^j \\
\eta_3 &= \mathcal{F}_h^j\frac{1}{\overline{Y}} \\
\delta &= \Big[2\mathcal{F}_j^i + (n-2)\mathcal{F}_h^j\Big]\frac{1}{\overline{Y}} + \mathcal{F}_0^j = \eta_1 + \Big[\mathcal{F}_j^i + (n-2)\mathcal{F}_h^j\Big]\frac{1}{\overline{Y}} \qquad \textbf{(A2)}
\end{aligned}$$

An intuitive explanation of the last expression for δ goes as follows. A tariff on good j (imposed by country i) changes the demand for good i as if the price of good j had increased (δ) minus the substitution effects abroad, since only domestic demand shifts, whereas foreign demand remains unaltered in the first place. The cross-price effects are equal across countries, because of the symmetry.

If η_1 is positive, then $\frac{\eta_1}{\delta}$ is only larger than one if the cross-price effects are negative. Then, however, δ might become negative. If η_1 is negative, $\frac{\eta_1}{\delta}$ is always smaller than one, since this case can only occur when the cross-price effects are negative.

(34) This equality can easily be proved by comparing the expressions for η_1 and η_2.

A.1.3 Signs of the elasticities

The signs of the elasticities of the demand function depend on the properties of the underlying utility function.

- $\mathcal{F}_0^i(\mathcal{F}_0^j)$ denotes the change of a country's demand for the domestic (foreign) good with respect to its income. If the good is a normal (inferior) good, this term is positive (negative). We have assumed that each country spends a positive fraction of its income on all goods. If we assume that this holds as well for an additional unit of income, all goods are normal goods. $\Rightarrow \mathcal{F}_0^i(\mathcal{F}_0^j) > 0$

- $\mathcal{F}_i^i(\mathcal{F}_j^j)$ denotes the own price effect of a domestic (foreign) good. This effect is negative for normal goods and positive for Giffen goods. If we assume that all goods are normal with respect to changes in income, we have no Giffen goods,(35) and so the demand for a good will always decrease when its price increases. $\Rightarrow \mathcal{F}_i^i(\mathcal{F}_j^j) < 0$

- $\mathcal{F}_j^i, j \neq i$ is the cross-price effect of the demand for good i with respect to the price of good j. If i and j are substitutes (complements), the cross-price effect is positive (negative), assuming that good j is a normal good. In other words, if the demand for j falls when it becomes more expensive, the demand for i falls as well if it is a complement, and rises if i is a substitute for j. If j is a Giffen good, it is the other way around. However, since the case of Giffen goods is rather theoretical, we shall neglect it. $\Rightarrow \mathcal{F}_j^i > 0 (< 0)$ if i, j are substitutes (complements) and normal goods.

We summarise the possible combinations of the features of the expenditure function and how they affect the signs of the elasticities of tariffs and of the (real) prices in Table B.

If not noted otherwise, we shall assume that all goods are normal and substitutes and so η_1, η_2, η_3 and δ are positive and, according to equation (**A2**), δ is larger than η_1.

(35) The Slutsky equation requires that Giffen goods are strongly inferior goods.

Table B: The tariff and real price elasticity of demand

Own price effect	*normal*	*Giffen*	*normal*	*Giffen*
Cross-price effect	*Substitutes*		*Complements*	
	$\mathcal{F}^i_i<0$, $\mathcal{F}^i_j>0$	$\mathcal{F}^i_i>0$, $\mathcal{F}^i_j<0$ $\mathcal{F}^j_0<0$	$\mathcal{F}^i_i<0$, $\mathcal{F}^i_j<0$	$\mathcal{F}^i_i>0$, $\mathcal{F}^i_j>0$ $\mathcal{F}^j_0<0$
η_1	**positive**	?	positive	positive
η_2	**positive**	negative	positive	?
η_3	**positive**	negative	negative	positive
δ	**positive**	negative	?	positive

A.2 Deriving the reduced form

We shall reduce the economy's model, equations (**1**) – (**8**), to two equations that express the equilibrium values of employment and CPI in terms of the policy instruments, money supplies and tariffs, and of the model parameters.

We assume that the expected money supply (more precisely, its deviation) for wage-setters is zero. Substituting equation (**3**) into (**2**) gives:

$$p_i = \alpha l_i + x \tag{A3}$$

Substituting (**A3**) and (**1**) into (**4**) yields the reduced form for employment:

$$l_i = m_i - m_i^e = m_i \tag{A4}$$

Thus, employment changes one-for-one with the domestic money supply, and is not affected by the other policy variables, that is, foreign money supply or tariffs. Substituting (**10**) into (**A3**) and (**1**) gives the equilibrium values of the output and its price level:

$$p_i = \alpha m_i + x \tag{A5}$$

$$y_i = (1-\alpha) m_i - x \tag{A6}$$

We substitute equation (**A6**) into equation (**7**) and solve for $\delta \sum_{\substack{j=1 \\ j\neq i}}^{n} z_{ij}$. Substituting this expression and equation (**A5**) into equation (**8**) gives the reduced form for the CPI:

$$q_i = \underbrace{(\alpha + \tfrac{\beta^2(1-\alpha)}{\delta(n-1)})}_{\lambda} m_i - \underbrace{\tfrac{\beta^2(1-\alpha)}{\delta(n-1)^2}}_{\kappa} \sum_{\substack{j=1\\j\neq i}} m_j +$$

$$\tfrac{\beta}{n-1}\left(1-\tfrac{\eta_1}{\delta}\right)\sum_{\substack{j=1\\j\neq i}}^{n}\theta_{ij} + \tfrac{\beta}{n-1}\tfrac{\eta_2}{\delta}\sum_{\substack{j=1\\j\neq i}}^{n}\theta_{ji} - \tfrac{\beta}{n-1}\tfrac{\eta_3}{\delta}\sum_{\substack{j=1\\j\neq i}}^{n}\sum_{\substack{h=1\\h\neq i}}^{n}\theta_{jh} + x$$

Setting the first coefficient to λ and the second to κ, the reduced form for q_i can be rewritten as:

$$\mathbf{q_i} = \lambda\mathbf{m_i} - \kappa\sum_{\substack{\mathbf{j=1}\\\mathbf{j\neq i}}}^{\mathbf{n}}\mathbf{m_j} + \underbrace{\tfrac{\beta}{n-1}\left[\left(1-\tfrac{\eta_1}{\delta}\right)\sum_{\substack{j=1\\j\neq i}}^{n}\theta_{ij} + \tfrac{\eta_2}{\delta}\sum_{\substack{j=1\\j\neq i}}^{n}\theta_{ji} - \tfrac{\eta_3}{\delta}\sum_{\substack{j=1\\j\neq i}}^{n}\sum_{\substack{h=1\\h\neq i}}^{n}\theta_{jh}\right]}_{\mathbf{\Theta}} + \mathbf{x}$$

The coefficients λ and κ are positive, since $0 < \alpha < 1$ and $n \geq 3$.

A.3 Solving the equilibrium with a coalition

We shall keep this analysis very short, since the main steps can be checked in the Appendix of Kohler (1996).

The countries $j = 1, \ldots, k$ are members of the coalition C, the countries $i = k+1, \ldots, n$ are not in the coalition. The optimisation problem that has to be solved by the monetary authority of a country can be summarised as follows. Outside the coalition, L_i is minimised with respect to the own money supply; in the coalition, L_i is minimised with respect to the money supplies of all coalition members.

$$min_{m_i,m_j} L_i = \frac{1}{2}\left(\sigma m_i^2 + (\lambda m_i - \kappa \sum_{\substack{j=1\\j\neq i}}^{n} m_j + \Theta + x)^2\right)$$

The reaction function of a country outside the coalition A country that is not in the coalition sets its own money supply so as to minimise its losses. It takes the others' money supplies as given (Nash conjectures).

$$min_{m_i}\ L_i \qquad \text{s.t. } m_j = \overline{m_j} \quad \forall j \neq i$$

The first-order condition and the symmetry assumption for outsiders give the money supply of a non-member as a function of the coalition's money supply:

$$m^*_{nc} = \underbrace{\frac{\lambda\kappa}{\sigma + \lambda^2 - \lambda\kappa(n-k-1)}}_{\kappa\vartheta} \sum_{j=1}^{k} \overline{m}_{j,c} - \vartheta\Big[\Theta_{nc} + x\Big] \qquad \textbf{(A7)}$$

The reaction function of a coalition member The coalition solves its optimisation problem subject to a given money supply of the non-members:

$$min_{m_j \in C}\ \mathcal{L} = \sum_{j=1}^{k} \frac{1}{k} L_j \qquad \text{s.t. } m_i = \overline{m}_{i,nc} \quad \forall\, i = k+1, \ldots, n$$

The first-order condition, together with the symmetry assumption for the coalition money supplies, gives the coalition member's reaction function, dependent on the non-members' money supplies.

$$m^*_c = \frac{\lambda - \kappa(k-1)}{\sigma + (\lambda - \kappa(k-1))^2} \left[\kappa \sum_{i=k+1}^{n} \overline{m}_{i,nc} - \Big(\Theta_c + x\Big)\right] \qquad \textbf{(A8)}$$

The equilibrium Replacing the non-members' money supply in equation (**A8**) with equation (**A7**) gives the equilibrium money supply of a coalition member:

$$\begin{aligned} m^*_c \quad &= \quad - \underbrace{\frac{(\lambda-\kappa(k-1))}{\sigma+(\lambda-\kappa(k-1))(\lambda-\kappa(k-1)-\kappa^2(n-k)\vartheta k\Big)}}_{\rho} \Big[\kappa(n-k)\vartheta\Theta_{nc} + \Theta_c\Big] \\ &\quad -\rho\Big[\kappa(n-k)\vartheta + 1\Big] x \end{aligned}$$

and the equilibrium money supply of a non-member:

$$m^*_{nc} = -\underbrace{\Big[\kappa^2\vartheta^2 k\rho(n-k) + \vartheta\Big]}_{\omega} \Theta_{nc} - \kappa\vartheta k\rho\Theta_c - \Big[\omega + \kappa\vartheta k\rho\Big] x$$

The sign of the coefficients ϑ is positive, since it can be rewritten as $\vartheta = \frac{\lambda\kappa}{\sigma+\lambda(\lambda-\kappa(n-k-1))}$ and
$\lambda - \kappa(n-k-1) = \lambda\frac{k}{n-1} + \alpha\frac{n-k-1}{n-1} > 0$. □

ρ can be rewritten as $\rho = \tilde{\rho}\,\frac{\sigma+\lambda(\lambda-\kappa(n-k-1))}{\sigma+\lambda+\lambda\kappa}$. ρ is positive since $\tilde{\rho}$ is positive. For the proof, see Kohler (1996), Appendix B.1 ($\tilde{\rho}$ is equal to the coefficient ρ discussed on pages 28ff.). □

Appendix B
The simulation results

In the following, we shall present the results of the simulation analysis. There is no *a priori* reason for a specific value for any of the parameters, so we chose values in the middle of the defined ranges for each parameter. Consequently, a robustness analysis was performed, the results of which are presented subsequently. The 'standard values', that is, the values if not noted otherwise, are:

$$\alpha = \beta = \tau = 0.5, \sigma = 1, \ \ \mathcal{F}_j^j = -0.5, \ \ \mathcal{F}_j^i = 0.45$$

The elasticities are calculated according to:

$$\eta_1 = \tfrac{\beta}{n-1}(1 + \mathcal{F}_j^i) \quad \text{and} \quad \eta_2 = \tfrac{\beta}{n-1}(1 - \mathcal{F}_j^j)$$
$$\eta_3 = \tfrac{1}{n-2}(\eta_2 - \eta_1) \quad \text{and} \quad \delta = \eta_1 + \eta_2 - \tfrac{\beta}{n-1}$$

This ensures that η_1 and η_2 remain within the limits $\frac{\beta}{n-1}$ and $2\frac{\beta}{n-1}$, and η_3 remains between zero and $\frac{\beta}{n-1}$. In addition, $(-\mathcal{F}_j^j)$ must always be higher than $\mathcal{F}_j^i$ if η_3 has to be positive.

B.1 Threshold tariffs

For each set of parameter values, we calculate the minimum tariff level τ that can sustain full coordination. In Table C, we present the results of the **univariate analysis**.
In short, the threshold tariff decreases in $\alpha, \beta, (-\mathcal{F}_j^j)$ and $\mathcal{F}_j^i$; it increases in σ and n.

The damage of the tariff Θ_{nc} increases with the propensity to import β and the tariff elasticities of the demand, η_1 and η_2 (which increase in $\mathcal{F}_j^i$ and $\mathcal{F}_j^j$, respectively). Consequently, the threshold tariff level is lower when these parameters take higher values.

The inverse is true for the number of countries n; the higher n, the less the damage caused by the tariff, since the trade volume with one country decreases with the number of trading partners $(n-1)$. Since the damage caused by tariffs decreases with n, the threshold tariff level must increase with n.

Table C: The threshold tariff: univariate analysis

α	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5
τ^*	3.7	2.65	1.95	1.5	0.15	0.9	0.7	0.55	0.45
α	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	
τ^*	0.35	0.3	0.25	0.2	0.15	0.1	0.06	0.04	
β	0.1-0.2		0.25-0.4		0.45-0.6		0.65-0.9		
τ^*	0.55		0.5		0.45		0.4		
σ	0.1	0.2	0.3	0.4-0.5	0.6-0.7	0.8-1.2	1.3-2.3	2.4-2.9	3-4.6
τ^*	0.15	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6
n	3	4-5	6-8	9-22					
τ^*	0.0	0.3	0.4	0.5					
$\mathcal{F}_j^i$	0.1			0.2			0.3		
-$\mathcal{F}_j^j$	0.1-0.2	0.3-0.6	0.7–0.9	0.2	0.3-0.5	0.6-0.9	0.3-0.5	0.6-0.9	
τ^*	0.6	0.5	0.4	0.6	0.5	0.4	0.5	0.4	
$\mathcal{F}_j^i$	0.4		0.5		0.6		0.7	0.8	0.9
-$\mathcal{F}_j^j$	0.4-0.6	0.7-0.9	0.5-0.6	0.7-0.9	0.6	0.7-0.9	0.7-0.9	0.8-0.9	0.9
τ^*	0.5	0.4	0.5	0.4	0.5	0.4	0.4	0.4	0.4

σ represents the weight of the employment target in the policy-maker's objective function. A low σ means that inflation is relatively more important and, hence, the tariff punishment that creates inflation has more impact, too. Therefore, for low σ, a lower tariff level will be sufficient to sustain full co-operation.

Changes of α show the largest impact on the threshold tariff level. The reason is that α influences the relative importance of being able to free-ride and avoiding the tariff punishment. A high α implies that κ, which represents the impact of foreign monetary policy on the domestic economy, is low. Therefore, coordinated and uncoordinated monetary policies do not differ very much, and gains from free-riding are relatively small for high α. It does then not pay off to undergo a tariff punishment, which does not change with α. Hence, the threshold tariff level is lower when α is higher.

The **multivariate analysis** does not give results much different from the univariate analysis. Hence, in Table D we summarise only the results for the most influential parameter, α.(36) We report the threshold tariff level that supports full coordination for all possible values of all parameters except for α, which is quoted explicitly. Again, α is the most influential parameter, and affects the threshold tariff level inversely.

Table D: The threshold tariff: multivariate analysis

α=1.0	$\tau \geq 0.1$	*sustains all*
α=0.9	$\tau \geq 0.1$	*sustains all*
α=0.8	$\tau \geq 0.3$	*sustains all*
α=0.7	$\tau \geq 0.3$	*sustains most*
α=0.6	$\tau \geq 0.5$	*sustains most*
α=0.5	$\tau \geq 0.9/0.7$	*sustains all/most*
α=0.4	$\tau \geq 0.9/0.7$	*sustains all/most*
α=0.3	τ	*between 0.5 and 1.7*
α=0.2	τ	*mostly above 2, for very high* $\beta(\geq 0.8)$ *around 1*

B.2 Punishment of outsiders

If the coalition cannot commit credibly to the tariff threat on eg institutional grounds, it may pay off for the coalition to actually punish in order to build up a reputation. Punishment of outsiders pays off if the gains from the 'additional' coordination gained through reputation (that is, coordination beyond three countries) exceeds the costs of punishment. We calculated the costs of punishment and balanced it against the gains, assuming that all countries except for the 'outsiders' join the punishment scheme. The penal tariff is equal to the threshold tariff level for each parameter constellation. We have determined the (maximum) number of outsiders that may be punished. We can derive from this number the minimum coalition size that is needed for punishment of outsiders to pays off.

If we have six countries, it pays always to punish up to two outsiders; if we have seven countries, it pays to punish up to three outsiders; if we have eight countries, it pays to punish up to four outsiders. Since there are always three countries in the coalition when there are no tariff

(36) We report here only a summary of the multivariate analysis. The detailed results can be obtained on request from the author.

threats, this means that punishment of outsiders is always worthwhile for the coalition, if this ensures that at least one more member joins the coalition.

Table E: Minimum number of countries where punishment of outsiders pays

	Parameter	*Eff. tariff*	*Number of countries n =*							
		τ^*	3	4	5	6	7	8	9	10
α	0.1	3.7	0	0	0	2	3	4	5	6
	0.2	1.95	0	0	0	2	3	4	5	6
	0.3	1.1	0	0	0	2	3	4	5	6
	0.4	0.7	0	0	0	2	3	4	5	6
	0.5	0.45	0	0	0	2	3	4	5	6
	0.6	0.3	0	0	0	2	3	4	5	6
	0.7	0.2	0	0	0	2	3	4	5	6
	0.8	0.09	0	0	0	2	3	4	5	6
	0.9	0.04	0	0	0	2	3	4	5	6
β	0.1-0.2	0.55	0	0	0	2	3	4	5	6
	0.3-0.4	0.5	0	0	0	2	3	4	5	6
	0.5-0.6	0.45	0	0	0	2	3	4	5	6
	0.7-0.9	0.4	0	0	0	2	3	4	5	6
σ	0.1	0.15	0	0	0	2	3	4	5	6
	0.2	0.25	0	0	0	2	3	4	5	6
	0.3	0.3	0	0	0	2	3	4	5	6
	0.4-0.5	0.35	0	0	0	2	3	4	5	6
	0.6-0.7	0.4	0	0	0	2	3	4	5	6
	0.8-1.2	0.45	0	0	0	2	3	4	5	6
	1.3-2.3	0.5	0	0	0	2	3	4	5	6
	2.4-2.9	0.55	0	0	0	2	3	4	5	6

We present the results of the univariate sensitivity analysis in Table E. The result described above (if the coalition gains only one more member, the tariff punishment scheme pays) holds for all parameter values.[37]

[37] $\mathcal{F}^i_j$ and $\mathcal{F}^j_j$, though not reported here, do not change the results.

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