The Utopia of Implementing Monetary Policy Cooperation through Domestic Institutions[+]

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Abstract. In a wide variety of international macro models monetary policy cooperation is optimal, non-cooperative policies are inefficient, but optimal policies can be attained noncooperatively by optimal design of domestic institutions. W show that given endogenous institutional design, inefficiencies of noncooperation cannot and will not be eliminated. Credible contracts are introduced as the contracts that would be chosen by the governments based on their individual rationality. These will be inefficient when compared to the optimal ones. Implementation of the latter implicitly embeds an assumption about cooperation at the delegation stage, which is inconsistent with the advocated non-cooperative nature of the solution. A general solution method for credible contracts and an example from international monetary policy cooperation are considered. Our results could explain some inefficiencies of existing delegation schemes and hint to a stronger coordinating role for supranational authorities in international policy coordination.

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1. Introduction

A large body of literature has grown dealing with optimal delegation of macroeconomic policy in an international context, much of it being reviewed by Persson and Tabellini (2000). In this framework, optimal contracts or targeting regimes over some macroeconomic variable are viewed as panacea for solving inherent inefficiencies of non-cooperative (and discretionary) policymaking. Notably, much of the work concerning monetary policy institutions adopts this line of reasoning. The inefficiencies that optimal delegation is supposed to 'fix' in this case are problems due to non-cooperative policymaking in the presence of policy spillovers in a multi-country world (and/or 'credibility' problems like the inflation bias). A recurrent result (see e.g. the seminal contributions by Persson and Tabellini 1995, 1996, 2000) that the *cooperative optimum* (to be defined) can be achieved in a decentralised, non-cooperative manner by *delegating through optimal inflation contracts.* This is done by supposing that before the actual policy game takes place, there is a 'pregame', an 'institutional design stage', where governments choose the appropriate delegation scheme for their central banks that implements the optimum. This paper argues that, although these delegation schemes would be desirable, they are also non-implementable, at least not with the set of assumptions usually made. In our view, the main fallacy consists in that all this literature implicitly assumes cooperation (or some form of coordination) at the 'delegation stage', which is hard to reconcile with the idea of 'purely non-cooperative implementation of the cooperative optimum'. It is the purpose of this paper to develop this argument analytically by explicitly modelling the 'institutional design stage' as part of the game and regarding delegation parameters as decision variables of the government. Then, solving the extensive form game by backward induction, we find the contracts that will be chosen by the government and show they are different from those implementing the optimum. This has both descriptive and normative implications for the design of monetary institutions and international agreements.

In the international policy context, it has been long recognised (following Hamada 1976) that cooperative[1] policymaking is Pareto optimal when sovereign policymaking has externalities on the other countries. Typically, externalities take the form of conflicts over shock stabilisation or over preferred levels of macroeconomic outcomes. It has also been recognised that this optimum is not enforceable for various reasons (individual incentives to deviate, suboptimality of cooperation when commitment with respect to the domestic private sector is impossible, uncertainty regarding models, loss functions, etc) - all these issues are extensively reviewed in Canzoneri and Henderson (1991) or Ghosh and Masson (1994). Given individual incentives to deviate from the cooperative policies and optimality of cooperation the literature has moved towards identifying mechanisms that sustain the collusive outcome. Again, as we abstract from repeated game mechanisms[2] we focus on the 'institutional design' approach pioneered by Persson and Tabellini

[1] We adopt the game-theoretical definition of cooperation as joint optimisation by a group of players of their payoffs, implying a 'pregame' and the possibility of binding agreements. Coordination would by contrast mean choosing one particular equilibrium in the Nash Equilibirum set of the non-cooperative game (this might imply the presence of an external enforcing mechanism). Exchange of information is captured by the non-cooperative policymaking case.

[2] See Canzoneri and Henderson (1991) or Ghosh and Masson (1994) for an account of these.

(1995). This focus is reinforced in the international context by an observation made by Rogoff (1985b), showing that in the presence of domestic credibility problems as the ones reviewed above cooperation might even be welfare-reducing[3]. Hence, institutional design could act as a solution to both problems, namely discretion and non-cooperative policymaking.

This is exactly the approach taken by Persson and Tabellini (1995, 1996, 2000) and Jensen (2000). Present inefficiencies due to non-cooperation in the presence of externalities and/or domestic credibility problems, delegation to independent central bankers is seen as a possible solution. In Persson and Tabellini (1995), in a non-parametric stochastic two-country model capturing interdependencies, various institutional arrangements are considered. Besides interpreting existing arrangements (exchange rate pegs, monetary unions, etc) through an 'optimal contracts' lens they also provide normative implications. One is a direct consequence of the Folk Theorem in Delegation Games by Fershtman, Judd and Kalai (1991), where it is argued that in a two-player game the principals can obtain every Pareto optimal outcome as the unique subgame perfect Nash Equilibrium of the delegation game via delegating with some contracts written on target compensation form, as long as these contracts become common knowledge. In the international monetary policy game of Persson and Tabellini, this would mean delegation by the governments to the central banks by some non-linear discontinuous performance contracts with state-dependent parameters written directly over welfare functions. These are indeed in the spirit of Fershtman et al (1991), but are also highly non-realistic and difficult to implement. Hence, in Persson and Tabellini (1995, 1996, 2000) they move to analysing linear performance contracts (usually specified over inflation), again written by the governments before the game is played, in an 'institutional design' stage; they can be designed such that the inefficiencies related to both discretionarity and non-cooperative policymaking are eliminated. The optimal contracts hence found are still state-contingent, which is a non-desirable feature as it makes them difficult to implement (being informationally demanding and implying the institution changes each time a shock occurs). Making them state-independent induces again inefficiency of outcomes, hinting to the fact that monetary policy institutional design faces a second-best problem. However, Jensen (2000) addresses this issue by finding some transfer functions that implement the cooperative outcome and have also state-independent parameters. These functions penalise quadratically inflation deviations from a certain level (chosen by the government) as well as inflation differentials between the two countries. He also provides interpretations of these contracts in terms of real-life institutions.

A general criticism of this line of research is that welfare conclusions and prescriptios cannot be properly addressed in a model that lacks microfoundations (Obstfeld and Rogoff 1996). However, recent research shows that the coclusion on optimal design of institutions carries over to more realistic setups in the new open macroeconomics tradition. Indeed, in a general equilibrium fully micro-founded

[3]Oudiz and Sachs (1985) derive a somehow converse result: domestic commitment can harm in the absence of cooperation. Both results are interpreted by Canzoneri and Henderson (1991) as particular cases of a more general one: coalitions of only subsets of players are inefficient.

two-country model, Benigno and Benigno (2002) show that domestic inflation targeting regimes implementing optimal cooperative policies non-cooperatively do exist. It certainly seems that he last problem the literature had in deriving normative prescriptions (i.e., having a microfounded model to analyse welfare) is overcome.

In the remainder of the paper we will try to show why, although desirable and interesting theoretical constructs, these contracts or targeting regimes are no 'non-cooperative' ways of achieving the cooperative outcome. We argue that if an 'institutional design stage' is to be considered, than it should also be explicitly modelled. It is important to note that once we consider transfer functions we are no longer in the conditions of the Folk Theorem in Delegation Games. Fershtman et al dealt with what we would call 'point implementation', as by their 'take-it-or-leave-it' target compensation functions the equilibrium in the agents' game can be made identical to a Pareto optimum. Once we make the transfer functions linear (e.g.), the equilibrium in the agents' game will depend on the delegation in no simple way as this will change their reaction functions. In order to pin down the equilibrium one has to pin down some values for the delegation parameters.

That would imply that at the first stage governments choose the delegation parameters in a non-cooperative manner, taking into account the reaction functions of the central banks at the policy stage (i.e. by backward induction). If one is to think about governments designing institutions in a non-cooperative manner, then the best way to model this is in our view based on individual rationality and hence subgame perfection (due to the fact that the game is in extensive form).As the contracts chosen this way (credible contracts as we shall call them) turn out to be different from the 'optimal' ones, it is clear that in order to select the right contracts cooperation of governments or some form or coordination is needed at the delegation stage. But then, if binding agreements are possible, why is delegation needed in the first place? Section 2 presents a formal version of the argument in a general framework, Section 3 presents an example in the same setup as Persson and Tabellini (1996, 2000) and Section 4 concludes.

2. A general framework and solution method

In this section the solution method for what we will call 'credible contracts' (as a shorthand notation for subgame perfect contracts) as opposed to optimal contracts (see e.g. Persson and Tabellini 2000 and references therein) is described in a two-country model with policy spillovers[4]. Following most of the literature on policy coordination and institutional design reviewed above, suppose that in each country a policymaker minimises an aggregate loss function defined over deviations of some macroeconomic variables stacked in the vector $\mathbf{X}$ from some target (socially desirable) levels $\boldsymbol{\tau}$ ($\mathbf{X}$ would include e.g. inflation, the output gap, the exchange rate, etc)[5]. Let the home and foreign countries losses take the form $L(\mathbf{X};\boldsymbol{\tau})$ and $L^*(\mathbf{X}^*;\boldsymbol{\tau}^*)$ respectively (a start will typically denote a foreign variable).

[4]Specific (parametric) examples of models most related to this one are i.a. Persson and Tabellini (1995, 2000), Bilbiie 2000. We provide for an example in the next section.

[5]This loss function is most of the times quadratic and is usually directly postulated, although possible to derive from a microfounded model taking into account individual preferences - see e.g. Woodford 1999, Benigno and Benigno 2002). It is usually regarded as a quadratic approximation of and aggregate welfare function describing society's preferences.

Suppose that in each country the policymaker has at its disposal one policy instrument (such as the interest rate or growth in a monetary aggregate for monetary policy) and denote this by i. Additionally, assume the model is stochastic, hence each variable will be hit by a stochastic shock and let the vector of such shocks be denoted by $\boldsymbol{\epsilon}$. Apart from the policymaker, in each country there is a private sector forming expectations over some relevant subset of variables of $\mathbf{X}$ and hence ultimately over the policy instruments conditional on some information available one period in advance (Ω_{-1}) according to:

$$i^e = E\left[i \mid \Omega_{-1}\right], i^{e*} = E\left[i^* \mid \Omega^*_{-1}\right] \tag{2.1}$$

As the two countries are interdependent, we also assume that the instrument in one country influences at least one of the macroeconomic variables of the other, either directly or indirectly (e.g. through a variable such as the exchange rate). With these assumptions, the relevant macroeconomic variables are determined and interrelated by a certain model, and ultimately each variable can be expressed as a function of the instruments, expectations and shocks in both countries:

$$\mathbf{X} = \mathbf{X}\left(i, i^*, i^e, i^{e*}, \boldsymbol{\epsilon}, \boldsymbol{\epsilon}^*\right), \mathbf{X}^* = \mathbf{X}^*\left(i, i^*, i^e, i^{e*}, \boldsymbol{\epsilon}, \boldsymbol{\epsilon}^*\right) \tag{2.2}$$

Substituting (2) in the loss functions the latter are obtained as functions of instruments, expectations, shocks and target levels:

$$L = L\left(i, i^*, i^e, i^{e*}, \boldsymbol{\epsilon}, \boldsymbol{\epsilon}^*; \boldsymbol{\tau}\right), L^* = L^*\left(i, i^*, i^e, i^{e*}, \boldsymbol{\epsilon}, \boldsymbol{\epsilon}^*; \boldsymbol{\tau}^*\right) \tag{2.3}$$

Strategic interaction in this model would result from heterogeneity of targets ($\boldsymbol{\tau} \neq \boldsymbol{\tau}^*$) and from different preferences for the stabilisation of shocks, when there are spillovers. Assuming further L, L^* are differentiable, the policies would have positive or negative externalities depending on whether $\frac{\partial L(\cdot)}{\partial i^*}, \frac{\partial L^*(\cdot)}{\partial i} \gtreqless 0$. Also, the presence of a private sector forming rational expectations of some variable(s) combined with a real distortion in the economy would give rise to domestic incentives to deviate from optimality (defined below), i.e. not related to cross-country spillovers. This is the case in the 'dynamic inconsistency' literature reviewed above concerning monetary policy. Suppose that in choosing the policies, the policymaker faces the following timing in each period: (i) targets $\boldsymbol{\tau}, \boldsymbol{\tau}^*$ are revealed; (ii) expectations are formed, i^e, i^{e*} are determined; (iii) shocks $\boldsymbol{\epsilon}, \boldsymbol{\epsilon}^*$ are realised; (iv) policy instruments i, i^* are chosen simultaneously; (v) macroeconomic variables $\mathbf{X}, \mathbf{X}^*$ are fully determined.

2.1. The cooperative and commitment equilibrium, incentives to deviate and optimal delegation. Under the assumptions we made, a non-realistic policy regime whereby the two policymakers decide before stage (i) to cooperate (i.e. to minimise a joint loss function) and commit to an optimal rule with respect to the private sector will be Pareto optimal (see e.g. Persson and Tabellini 1995, 2000, Bilbiie 2000). Let this regime, which we shall use as a benchmark, be labeled '**the cooperative and commitment equilibrium**'. Ignoring different bargaining powers of the two authorities with no loss in generality the policy instruments at this equilibrium would be:

$$(i, i^*)^{cc} = \arg\min_{i, i^*} \left\{ \begin{array}{c} E\left[L\left(i, i^*, i^e, i^{*e}, \cdot\right) + L^*\left(i, i^*, i^e, i^{*e}, \cdot\right)\right] \ s.t. \\ i^e = E\left[i \mid \Omega_{-1}\right], i^{*e} = E\left[i^* \mid \Omega^*_{-1}\right] \end{array} \right\} \tag{2.4}$$

The optimal policy rules $i^{cc}(\boldsymbol{\epsilon},\boldsymbol{\epsilon}^*), i^{*cc}(\boldsymbol{\epsilon},\boldsymbol{\epsilon}^*)$will obey to (and can be found by solving for)[6] the following associated first-order conditions, rewritten after eliminating the Lagrange multipliers of the rational expectations constraints:

$$
\begin{aligned}
\frac{\partial E\left[L(\cdot)+L^*(\cdot)\right]}{\partial i}+E\left[\frac{\partial E\left[L(\cdot)+L^*(\cdot)\right]}{\partial i^e}\mid \Omega_{-1}\right] &= 0 \\
\frac{\partial E\left[L(\cdot)+L^*(\cdot)\right]}{\partial i^*}+E\left[\frac{\partial E\left[L(\cdot)+L^*(\cdot)\right]}{\partial i^{*e}}\mid \Omega^*_{-1}\right] &= 0
\end{aligned} \tag{2.5}
$$

Upon specifying functional forms for loss functions and for the models determining the macroeconomic variables, the policy rules are obtained by taking conditional expectations of the system (5), hence determining expected variables, and then substituting the latter in the original system (5).

However, the above described equilibrium is far from realistic. If one's priors about real-world policymaking are that this process is best described in a non-cooperative setup (i.e. binding agreements of any sort are not possible) then the appropriate equilibrium concept to use is discretionary Nash equilibrium. This argument is enforced by the fact that usually in the literature the policymakers have individual incentives to deviate from the optimal policy rules at the expense of the other country. The resulting equilibrium will obviously be inefficient, due to two reasons: ignoring the spillovers of policy to the other countries' loss function and ignoring externalities on the own-country private sector; being more specific about the source of inefficiencies would require a parametric example which we postpone to the next section.

Apart from repeated game mechanisms sustaining the equilibrium in (4) or (5) as a unique subgame perfect equilibrium[7] in the repeated version of the game described above, delegation has been considered as a non-cooperative solution to inefficiencies, i.a. in the pioneering work by Persson and Tabellini 1995. The argument reviewed in the introduction can be expressed here as follows. Consider that at stage (0), before stage (i) above, each government delegates the policy to an independent policy authority by imposing a certain transfer function $T\left(\bar{\mathbf{X}}\right)$, where $\bar{\mathbf{X}}$ would be a subset of the relevant macroeconomic variables (e.g. only inflation for inflation contracts). Ultimately, this function can also be defined over instruments and shocks, hence delegation would mean assigning loss functions of the form (where superscript D stands for 'delegated'):

$$
\begin{aligned}
L^D(\cdot;T) &= L(\cdot)+T\left(i,i^*,\boldsymbol{\epsilon},\boldsymbol{\epsilon}^*;\boldsymbol{\tau},\boldsymbol{\tau}^*\right) \\
L^{D*}(\cdot;T^*) &= L^*(\cdot)+T^*\left(i,i^*,\boldsymbol{\epsilon},\boldsymbol{\epsilon}^*;\boldsymbol{\tau},\boldsymbol{\tau}^*\right)
\end{aligned} \tag{2.6}
$$

The independent authorities would thus face these loss functions when choosing their policy instruments simultaneously at stage (iv), in a non-cooperative and discretionary manner. The corresponding **discretionary Nash equilibrium** policy rules will be given by:

[6]Throughout we shall assume that certain properties of loss functions, policy sets, etc. are met so that the considered equilibria do exist and are unique, which is the case in most models considered in the literature.

[7]See Canzoneri and Gray 1985, chapters 4 and 5 and Ghosh and Masson 1994 for an extensive treatment of these.

$$
\begin{aligned}
i^{DN} &= \arg\min_{i} \left[L\left(i, i^*, i^e, i^{*e}, \cdot\right) + T\left(i, i^*, \cdot\right) \right] \\
i^{DN*} &= \arg\min_{i^*} \left[L^*\left(i, i^*, i^e, i^{*e}, \cdot\right) + T^*\left(i, i^*, \cdot\right) \right]
\end{aligned}
\tag{2.7}
$$

The policy instruments can be solved starting from the first order conditions given below, taking expectations of these to pin down expected variables and substituting these back in the original system:

$$
\begin{aligned}
\frac{\partial \left[L\left(i, i^*, i^e, i^{*e}, \cdot\right) + T\left(i, i^*, \cdot\right) \right]}{\partial i} &= 0 \\
\frac{\partial \left[L\left(i, i^*, i^e, i^{*e}, \cdot\right) + T^*\left(i, i^*, \cdot\right) \right]}{\partial i^*} &= 0
\end{aligned}
\tag{2.8}
$$

Consider first the case without delegation, i.e. $T\left(i, i^*, \cdot\right) = T^*\left(i, i^*, \cdot\right) = 0$. The two sources of inefficiencies mentioned before are obvious by comparing the systems (5) with the restricted (8) and observing the absence from the latter of some terms coming from ignoring externalities on (i) the other policymaker and (ii) the private sector. Solutions to this inefficiency usually considered in the literature would be equivalent to the governments choosing the functions $T\left(i, i^*, \cdot\right), T^*\left(i, i^*, \cdot\right)$ such that the solutions to the systems (5) and (8) become equivalent. It is easily seen by direct comparison that the chosen 'contracts' or transfer functions should fulfil (where instruments are evaluated at the cooperative and commitment optimum in (4)) :

$$
\begin{aligned}
\left(\frac{\partial T\left(i, i^*, \cdot\right)}{\partial i} \right)^{cc} &= \frac{\partial E\left[L^*\left(\cdot\right)\right]}{\partial i}\left(i^{cc}, i^{cc*}, \cdot\right) + E\left[\frac{\partial E\left[L\left(\cdot\right) + L^*\left(\cdot\right)\right]}{\partial i^e} \mid \Omega_{-1} \right]\left(i^{cc}, i^{cc*}, \cdot\right) \\
\left(\frac{\partial T^*\left(i, i^*, \cdot\right)}{\partial i^*} \right)^{cc} &= \frac{\partial E\left[L\left(\cdot\right)\right]}{\partial i^*}\left(i^{cc}, i^{cc*}, \cdot\right) + E\left[\frac{\partial E\left[L\left(\cdot\right) + L^*\left(\cdot\right)\right]}{\partial i^{*e}} \mid \Omega^*_{-1} \right]\left(i^{cc}, i^{cc*}, \cdot\right)
\end{aligned}
\tag{2.9}
$$

Specifying a certain functional form for the transfer functions usually results in a solvable system for the delegation parameters (again, under the convenient assumption that the transfer function is differentiable). To choose the most prominent example, linear inflation contracts, suppose T's are linear functions of the policy instruments and can be expressed as $T\left(i\right) = k + t\dot{i}$, where k and t are the delegation parameters to be chosen. Then it is clear that the system above fully determines t and t^* as $\partial T / \partial i = t$ and label the values hence determined 'optimal contracts', denoted by t^{cc} and t^{cc*}. In most cases, these marginal contracts are state-dependent (i.e. dependent on the realisation of the shocks), which makes them hard to implement and undermines their credibility. Jensen (2000) addresses this problem by showing how the first best in (4) can nevertheless be implemented through state-independent delegation by choosing a quadratic form for the transfer function T.

The general delegation argument in this framework is based on a Folk Theorem for Delegation Games in Fershtman et al. (1991), as argued by Persson and Tabellini (1995). This provides conditions under which in a two-principal-two-agent game every Pareto optimal outcome of the principals' game can become the unique subgame perfect equilibirum of the delegaiton game; this is done if each principal delegates to an agent and both contracts are public information. However, contracts consistent with the condition of this theorem would be of a form which does not seem easily mapped into real-world policy institutions, for instance in our example (for the home country):

$$
\begin{aligned}
(2.10)\quad T\left(i,i^*,\boldsymbol{\epsilon},\boldsymbol{\epsilon}^*\right) &= \begin{cases} \Upsilon, \text{if } L\left(i,i^*,\cdot\right), L^*\left(i,i^*,\cdot\right) \leq L^{cc}\left(\cdot\right), L^{cc*}\left(\cdot\right) \\ \Upsilon + c, c > 0 \text{ otherwise} \end{cases} \\
i\left(\boldsymbol{\epsilon},\boldsymbol{\epsilon}^*\right) &= \begin{cases} i^{cc}\left(\boldsymbol{\epsilon},\boldsymbol{\epsilon}^*\right), \text{iff } \left[T\left(\cdot\right), T^*\left(\cdot\right)\right] \leq \left(\Upsilon,\Upsilon\right) \\ i^{DN}\left(\boldsymbol{\epsilon},\boldsymbol{\epsilon}^*\right), \text{ otherwise} \end{cases}
\end{aligned}
$$

The strategies in (10), together with mirroring strategies for the foreign country, implement the first best once contracts are public information[8], but require that each penalty is written over *both payoffs directly.*

Although interesting theoretically, transferring this idea to 'optimal linear contracts' without qualification is dangerous. While this theorem shows that strategies of the form (10) implementing the cooperative optimum in a decentralised manner do *exist*, it says nothing about their implementability. Moreover, if one is to think about governments choosing a delegation scheme and facing a decision problem that can be reduced to choosing a set of parameters of the transfer function T, then implementation of the 'optimal contracts' is by no means insured. In the 'linear contracts' example, each government has a choice parameter (t as we called it), presumably over a compact set. Why would it then choose t^{cc} is far from obvious. Why, given that it 'knows' t^{cc}, has the ability to commit to it and actually chooses it, does the government need to delegate policy and not choose directly the optimal policy rule $i^{cc}\left(\boldsymbol{\epsilon},\boldsymbol{\epsilon}^*\right)$ is even less clear.

2.2. Incentives to delegate: credible contracts. We think that once decisions of the government concerning delegation are considered and called for, they should also be modelled explicitly. Our choice for doing that consists of thinking about the delegation stage (0) as a separate stage of the game, and modelling governments as rational agents having as strategies the parameters determining the transfer functions. The timing would then be: (0) governments delegate policies to independent authorities by imposing the transfer functions $T\left(\cdot\right)$, $T^*\left(\cdot\right)$; (i)-(v) same as before, considering delegation took place. The solution method would then be based on backward induction: policy authorities choose their policy instruments independently and discretionarily taking delegation as given; governments choose delegation parameters taking into account the choice of policy instruments made previously by the delegated authorities.

The policy rules governments face at stage (0) are $\left(i^{DN}, i^{DN*}\right)$ given by (7) and fulfilling the first order conditions (8). For the sake of simplicity and for their widespread use, restrict the functional form of the transfer functions to linear contracts ultimately written as $T\left(i\right) = k + t\dot{i}, T^*\left(i^*\right) = k^* + t^*\dot{i}^*$. The *credible contracts*[9] will then be determined by:

$$
\begin{aligned}
(2.11)\qquad t^p\left(\cdot\right) &= \arg\min_t \left\{EL\left[i^{DN}\left(t,t^*,\cdot\right), i^{DN*}\left(t,t^*,\cdot\right),\cdot\right]\right\} \\
t^{p*}\left(\cdot\right) &= \arg\min_{t^*} \left\{EL^*\left[i^{DN}\left(t,t^*,\cdot\right), i^{DN*}\left(t,t^*,\cdot\right),\cdot\right]\right\}
\end{aligned}
$$

[8]For details see Persson and Tabellini (1995); for the game-theoretical argument see Fershtman et al (1991).

[9]More precisely, Subgame Perfect Nash Equilibrium contracts.

The other parameters k, k^* can be chosen such that the participation constraint of the policy authority is met. The first order conditions that credible contracts fulfil[10] are:

$$\begin{aligned} \frac{\partial E\left[L\left(\cdot\right)\right]}{\partial i}\frac{\partial i^{DN}\left(t,t^*\right)}{\partial t}+\frac{\partial E\left[L\left(\cdot\right)\right]}{\partial i^*}\frac{\partial i^{DN*}\left(t,t^*\right)}{\partial t} &= 0 \\ \frac{\partial E\left[L^*\left(\cdot\right)\right]}{\partial i}\frac{\partial i^{DN}\left(t,t^*\right)}{\partial t^*}+\frac{\partial E\left[L^*\left(\cdot\right)\right]}{\partial i^*}\frac{\partial i^{DN*}\left(t,t^*\right)}{\partial t^*} &= 0 \end{aligned} \tag{2.12}$$

The objects in (9) and (11) would be different in most situations (i.e. when externalities are present, which is why one considers delegation in the first place). This implies that *optimal contracts* are not consistent with individual rationality of the governments, the cooperation problem being not solved but merely relocated to the delegation stage. To implement optimal contracts, cooperation or some form of coordination of governments/principals is unequivocally necessary. Note again the difference with the Folk Theorem in delegation games: here, by delegating the principal modifies the reaction functions of the agent in a linear way (or else, if contracts non-linear) instead of 'forcing' the Nash equilibrium to overlap with the desired Pareto optimum. Even with this form of delegation, the Nash equilibrium could be made identical to the Pareto optimum, but this is not compatible with individual incentives of governments. This shall become clearer in the following example, where credible and optimal contracts are clearly different, in an intuitive way.

3. Credible vs. Optimal Inflation Contracts in International Monetary Policy

We use a parameterised version of the model in the previous section for an illustrative example. The model is an adapted version of Persson and Tabellini (1996, 2000) or Bilbiie (2000) and consists of directly postulated reduced forms, although it can be derived from microfoundations (see Rogoff 1985b or Canzoneri and Henderson 1991). The world consists as before in two countries, each one being specialised in producing a consumer good, which is an imperfect substitute for the other country's good. This generates the main spillover of policy through the real exchange rate. Each country has a monetary policy instrument which it uses for short-run stabilisation (it being able to do so is insured, for instance, by some nominal rigidity, e.g. wage contracting). The policy is also subject to a credibility problem generated by a real distortion making the natural rate of output (employment) suboptimally low. The model parameters are symmetric for simplicity but the shocks hitting the economy are arbitrarily correlated. All variables are in log-differences, a star denotes a foreign-country variable (for brevity just the home country's model is presented) and time subscripts have been suppressed:

[10]Note that this can be done more generally for a certain functional form of T as long as it is differentiable; the only modification would be that the number of parameters would increase (for example, for Jensen quadratic contracts these would be three), and hence the number of first order conditions to solve.

$$y = \gamma(p - p^e) - \varepsilon \tag{3.1}$$
$$p = m \tag{3.2}$$
$$z \equiv s + p^* - p \tag{3.3}$$
$$z = \delta(y - y^*) \tag{3.4}$$
$$\pi = p + \beta z \tag{3.5}$$

Deviations of output growth y from the natural rate (normalised to zero) are defined in (13) by an usual expectations-augmented Phillips curve, where inflation surprises in producer price inflation p matter. For simplicity, in (14) we suppose the growth rate of money is the same as that of producer inflation (perfect controllability of the latter), abstracting hence from velocity shocks as their presence does not add any insights to the analysis. Real exchange rate appreciation z is defined in (15) as nominal depreciation plus the differential of producer inflation. (16) relates the relative prices z of the two goods to their relative demand, hence defining an inverse demand equation, where $\delta > 0$ is the inverse relative demand elasticity of outside goods. A higher supply of foreign goods reduces z (real appreciation) by inducing a relative excess demand for home goods. We ignore speculative shocks for simplicity (again, without affecting the results). Finally, consumer price index inflation π is producer inflation plus inflation induced by the consumption of foreign goods, where β is the share of the latter in the domestic consumption basket. Observe that the only source of uncertainty in the economy is given by adverse supply shocks $(\varepsilon, \varepsilon^*)$ with zero mean, different variances and arbitrary covariance $(\sigma^2_\varepsilon \lesseqgtr \sigma^2_{\varepsilon^*}, \sigma_{\varepsilon\varepsilon^*} \lesseqgtr 0)$.

The private sector forms rational expectations of producer inflation (and hence money growth), as the expectation of the latter over the distribution of shocks, conditional upon the information set Ω_{-1} of previous realisations of macroeconomic variables and model parameters:

$$p^e = m^e = E[p \mid \Omega_{-1}] = E[m \mid \Omega_{-1}] \tag{3.6}$$

Social welfare in each country is defined over variability of output and inflation from some socially desirable levels. For simplicity, normalise the socially optimal inflation to zero and suppose the desirable output θ is greater than the natural rate due to some real distortion (monopolistic competition, for instance). Then the policymakers' task is to minimise the expected value of the following conventional period loss function[11], using as instruments the money growth rates m:

$$L(\cdot) = \frac{1}{2}\left\{\pi^2 + \lambda(y - \theta)^2\right\} \tag{3.7}$$

We assume that the exchange rate does not enter the loss function (for a detailed justification see Bilbiie 2000) and $\theta > 0$ giving rise to the domestic inflation bias described in the previous sections. The timing is as in the previous section: just

[11] When the game is repeated over time, the policymakers can be regarded as minimising the intertemporal loss $W = E_0\left[\sum_{\tau=0}^{T}\delta^\tau L_\tau\right]$, where $\delta \in (0,1)$ is the discount factor. As the stage game is identical always, this is equivalent to period-by period minimisation.

substitute $\mathbf{X}$ with (y, π, p, z), i with m, $\boldsymbol{\epsilon}$ with ε and $\boldsymbol{\tau}$ with $(0,\theta)$. For the sake of brevity, we shall apply directly the solution method described in the last section, without getting into computational details.

3.1. The cooperative optimum vs. sovereign discretionary policy-making.

Using the solution method described in Section 2.1 the **cooperative and commitment equilibrium** (as in eqs 4 and 5) is attained in this example for the *optimal state-contingent policy rules*:

$$
\begin{aligned}
m^{cc}(\varepsilon, \varepsilon^*) &= \frac{b}{1+b\gamma}\varepsilon + \frac{d(1+2a-b\gamma)}{(1+b\gamma)\left((1+2a)^2+b\gamma\right)}(\varepsilon-\varepsilon^*) \\
m^{*cc}(\varepsilon, \varepsilon^*) &= \frac{b}{1+b\gamma}\varepsilon^* - \frac{d(1+2a-b\gamma)}{(1+b\gamma)\left((1+2a)^2+b\gamma\right)}(\varepsilon-\varepsilon^*)
\end{aligned} \tag{3.8}
$$

We used the change of notation $b = \lambda\gamma, a = \beta\delta\gamma$ and $d = \beta\delta$. At the optimum, the policymaker stabilises domestic supply shocks (due to their influence on output and inflation). It also stablises relative shocks $\varepsilon - \varepsilon^*$ due to their indirect impact on welfare through real exchange rate appreciation/depreciation[12]. The responses are optimal due to the cooperative features of the equilibrium. Note also the absence of the inflation bias due to commitment (expected policies are zero). Each policymaker internalises the effects of its instruments on both the other country's welfare and its domestic private sector.

The **non-cooperative and discretionary equilibrium** can be solved again by the corresponding method described in the previous section. Suppose delegation to an independent central bank has taken place before the stage game is played, at stage (0). For the moment we assume this takes the form of linear inflation contracts of the type considered by Persson and Tabellini[13]. Namely, each government imposes a transfer function on its central bank of the form $T = k + t\pi, T^* = k^* + t^*\pi^*$. The marginal penalties t and t^* are likely to be state-contingent. Given the linear nature of the model and linearity in stochastic shocks we choose to model this by assuming that each marginal penalty is additively separable in a state-independent and a state-dependent component, namely:

$$
\begin{aligned}
t &= \bar{t} + \tilde{t}(\varepsilon, \varepsilon^*) \text{ where } E\left[\bar{t}\right] = \bar{t} \text{ and } E\left[\tilde{t}\right] = 0 \\
t^* &= \bar{t}^* + \tilde{t}^*(\varepsilon, \varepsilon^*) \text{ where } E\left[\bar{t}^*\right] = \bar{t}^* \text{ and } E\left[\tilde{t}^*\right] = 0
\end{aligned} \tag{3.9}
$$

Given these linear penalties, each central bank will minimise its loss function modified as in the system (6). The Nash discretionary equilibrium policy instruments given delegation are found as in the system (7) in the previous section as (where the same change of notation as before was used and additionally

[12]For a more general solution and details see Persson and Tabellini 1996 and Bilbiie 2000. Notably, demand (velocity) shocks would be stabilised completely.

[13]In Bilbiie (2000) we show equivalence of linear inflation contracts and inflation targets *a la* Svensson (1997) in this framework. We shall focus only on contracts for the sake of exposition but the results applpy equally to delegating with a non-zero inflation target.

$A = (1+a)^2 + b\gamma, B = a(1+a)$):

$$
\begin{aligned}
(3.10)\quad m^{DN}(\theta,\varepsilon,\varepsilon^*;t,t^*) &= -\bar{t} + \frac{b}{1+a}\theta - \frac{(1+a)A}{A^2-B^2}\tilde{t} - \frac{(1+a)B}{A^2-B^2}\tilde{t}^* + \\
&\quad \frac{b}{A-B}\varepsilon + \frac{d\left(1+a^2\right)}{A^2-B^2}(\varepsilon-\varepsilon^*) \\
m^{*DN}(\theta,\varepsilon,\varepsilon^*;t,t^*) &= -\bar{t}^* + \frac{b}{1+a}\theta - \frac{(1+a)B}{A^2-B^2}\tilde{t} - \frac{(1+a)A}{A^2-B^2}\tilde{t}^* + \\
&\quad \frac{b}{A-B}\varepsilon^* - \frac{d\left(1+a^2\right)}{A^2-B^2}(\varepsilon-\varepsilon^*)
\end{aligned}
$$

The purely non-cooperative discretionary equilibrium without delegation ($\bar{t} = \tilde{t} = \bar{t}^* = \tilde{t}^* = 0$) features two inefficiencies, as expected. First, a familiar inflation bias (the θ term) is present in each country (and is the same in both due to the assumption on homogeneity of growth targets) due to discretionarity. Secondly, the responses to both domestic supply shocks and relative shocks are different from the optimal ones due to non-internalisation of policy externalities when acting non-cooperatively. The exact nature of the distortions will depend on the shocks and the values of parameters but as a general rule the policies would have a contractionary bias when a favourable shock hits (positive externalities) and would be too expansionary, at the other country's cost. when an adverse shock is realised . Following for instance Persson and Tabellini (1996) we shall call this a *stabilisation bias*[14].

Following the analysis in section 2.1 we can easily find the marginal penalties that would implement the cooperative and commitment optimum when policy is non-cooperative and discretionary. *Mutatis mutandis*, system (9) in this case translates to:

$$
\begin{aligned}
t^{cc}(\theta,\varepsilon,\varepsilon^*) &= \frac{1}{1+a}\left\{b\theta - a\pi^{*cc}(\varepsilon,\varepsilon^*)\right\} \\
(3.11)\qquad &= \frac{b}{1+a}\theta - \frac{ab}{(1+a)(1+b\gamma)}\varepsilon^* - \frac{2a^2b}{(1+b\gamma)\left[(1+2a)^2+b\gamma\right]}(\varepsilon-\varepsilon^*) \\
t^{*cc}(\theta,\varepsilon,\varepsilon^*) &= \frac{1}{1+a}\left\{b\theta - a\pi^{cc}(\varepsilon,\varepsilon^*)\right\} \\
&= \frac{b}{1+a}\theta - \frac{ab}{(1+a)(1+b\gamma)}\varepsilon + \frac{2a^2b}{(1+b\gamma)\left[(1+2a)^2+b\gamma\right]}(\varepsilon-\varepsilon^*)
\end{aligned}
$$

The marginal penalties are intuitive, given the assumptions. The first terms are the familiar ones correcting for the domestic inflation bias in each country. The other terms correct for suboptimal stabilisation of shocks. The penalty is weaker if the foreign country suffers an adverse supply shock ($\varepsilon^* > 0$) or a less sever supply shock as compared to the home country ($\varepsilon - \varepsilon^*$). In these two cases foreign inflation is positive and the real exchange rate appreciates at home. In this case the home policy is too contractionary and a reward (or lower penalty, depending on the θ term) for additional inflation is needed to correct for that.

[14]More details on interpretation of incentives in this equilibrium can again be found in Persson and Tabellini (1996), Bilbiie (2000) or Jensen (2000).

The marginal penalties being state-contingent is indeed intuitive. How 'state-dependent institutions' would be designed in practice is far from intuitive (for instance, they would be informationally demanding, but would also require changes in institutions for every realisation of shocks)[15]. If only state-independent contracts are feasible, then only the domestic incentives are corrected for, leaving suboptimal shock stabilisation unaltered. This problem is solved by Jensen (2000) by proposing a delegation scheme based on quadratic contracts with targets of the form: $T(\cdot) = \frac{1}{2}\left\{\alpha\left(\pi - \pi^B\right)^2 + \mu\left(\pi - \pi^*\right)^2\right\}$, where α, π^B, μ are decision variables of the government when delegating. In our example, following the same solution method the optimum is implemented for: $\left(\alpha = \frac{a}{1+2a}, \pi^B = -\frac{b}{a}\theta, \mu = -\frac{a}{1+a}\right)$. For details and an intuitive interpretation of this see Jensen (2000).

3.2. Credible contracts: the linear inflation contracts case. Although

linear contracts *a la* Persson and Tabellini implement the optimum, albeit with state-contingent parameters, and the *Jensen contracts* solve also the latter problem of state contingency, they are both opposable to the critique we formulated in the previous section and we shall see an example of this at work[16]. Earlier examples of this critique can be found in Bilbiie (2000) for a model similar to this one, as well as for a model without domestic credibility problems.

To see what contracts government will implement based only on their individual rationality and their perception of rationality of the agents (central banks) to which they delegate we follow the solution method outlined in section 2. By backward induction, at stage (0) when delegating governments face the policy rules contingent on contracts that we solved for previously in (22). They will then minimise the expected values of the social losses given by eq. 19 (and its foreign counterpart), where inflation and the output gap are evaluated at the delegated Nash Equilibrium. As to governments' control variables, we choose to model only the state-independent part of the contract as such. Hence, e.g. the 'home' government will only choose $\overline{t}$, and for finding the equilibrium state-contingent part of the contract $\tilde{t}(\varepsilon, \varepsilon^*)$ we will just use (21). Substituting $m^{DN}(\cdot; t, t^*), m^{*DN}(\cdot; t, t^*)$ in $E[L(\cdot)], E[L^*(\cdot)]$ and minimising the latter two with respect to $\overline{t}$ and $\overline{t^*}$ respectively yields the two first order conditions:

$$\begin{aligned} p^{DN}(\overline{t}, \tilde{t}, \overline{t}^*, \tilde{t}^*; \theta, \varepsilon, \varepsilon^*) &= 0 \\ p^{*DN}(\overline{t}, \tilde{t}, \overline{t}^*, \tilde{t}^*; \theta, \varepsilon, \varepsilon^*) &= 0 \end{aligned} \tag{3.12}$$

Substituting the Delegated Nash equilibrium money growth rates we get two equations in four unknowns $\overline{t}, \overline{t}^*, \tilde{t}(\varepsilon, \varepsilon^*), \tilde{t}^*(\varepsilon, \varepsilon^*)$. Using state independence of the first two and zero-mean of the last two one gets a solution for credible contracts

[15] For a critique of state-dependent delegation see for instance Jensen (2000).

[16] Jensen recognises this problem himself in the last paragraph of the mentioned paper '[...] incentives causing policymakers to deviate from cooperative policies would also cause governments to deviate from cooperative institutions', but he focuses on identification of optimal institutions and not their implementability.

as (where a and b are defined as before):

$$
\begin{aligned}
t^{p}(\varepsilon,\varepsilon^{*}) &= \frac{b}{1+a}\theta+\frac{b}{1+a}\varepsilon^{*}+\frac{b}{1+2a}(\varepsilon-\varepsilon^{*}) \\
t^{*p}(\varepsilon,\varepsilon^{*}) &= \frac{b}{1+a}\theta+\frac{b}{1+a}\varepsilon-\frac{b}{1+2a}(\varepsilon-\varepsilon^{*})
\end{aligned} \tag{3.13}
$$

We are now ready to compare these non-cooperative *credible contracts* with the *optimal contracts* implementing the first best, focusing for exposition on the home country. A first thing to note is that, maybe surprisingly so, the state-independent term leading to elimination of the systematic inflation bias is the same in $t^{cc}(\varepsilon,\varepsilon^{*})$ and $t^{p}(\varepsilon,\varepsilon^{*})$. Another way to read this is that if only state-independent delegation were possible, the two contracts would coincide, although they would then be both suboptimal in that they would not affect stabilisation of shocks.

The inefficiency of credible contracts comes from suboptimal responses to shocks (second and third term). Consider again the case where the foreign country is hit by an adverse supply shock $\varepsilon^{*}>0$ and this is less severe than in the home country (or equivalently, there is a larger favourable shock), i.e. $\varepsilon-\varepsilon^{*}>0$. In equilibrium π^{*} is greater than zero and there is a contractionary bias of the home country's monetary policy. In the optimal contract t^{cc}, both coefficients on shock stabilisation are *negative*: the optimal penalty in the home country decreases to correct for the deflationary bias. On the contrary, in the credible contract t^{p} both coefficients are *positive:* the penalty is increasing in ε and $\varepsilon-\varepsilon^{*}$, aggravating the contractionary bias of home policy. Equivalently, one may observe that the credible contract is always imposed so that inflation is zero, whereas in the considered case the optimal response would be a positive inflation. To achieve the zero inflation in the perfect equilibrium an increasing marginal penalty is needed. In the converse case, where the foreign country faces a favourable supply shock $\varepsilon^{*}<0$ relatively smaller than in the home country $(\varepsilon-\varepsilon^{*}<0)$ there is an expansionary bias of home monetary policy. This negative spillover would be eliminated through optimal delegation: the penalty becomes larger (see eq. 23) to reduce inflationary incentives. As the spillovers are ignored in the perfect equilibrium, the penalty will be smaller, tailored to achieving a zero inflation consistent with the first order condition when the optimal response should in fact target deflation.

The two contracts are different even when shocks are perfectly correlated, in the symmetric case whereby $\varepsilon=\varepsilon^{*}$. The optimal marginal penalty would be $t^{cc}=\frac{b}{1+a}\theta-\frac{ab}{(1+a)(1+b\gamma)}\varepsilon$, whereas the credible one is $t^{p}=\frac{b}{1+a}\theta+\frac{b}{1+a}\varepsilon$. An adverse common supply shock generating a contractionary bias is optimally corrected by a decrease in the penalty for additional inflation. Not recognising the positive externality that would result from both countries inflating more, at the delegation stage governments increase the penalty aggravating the deflationary bias.

The different contracts can be directly compared by substituting them in the best response functions (22)[17]. The linear optimal contracts t^{cc}, t^{*cc} implement the first best optimal money growth rates m^{cc}, m^{*cc}, and so do the Jensen quadratic contracts and the contracts consistent with the Folk Theorem in delegation games presented in (10). Without delegation, the Nash equilibrium policies would feature an inflation bias and suboptimal shock stabilisation. Delegation

[17] In Bilbiie (2000) we provide a more detailed welfare comparison of equilibria.

with credible contracts would mean elimination of the inflation bias but still sub-optimal shock stabilisation, so they will not lead to implementation of m^{cc}, m^{*cc}. By substituting t^p, t^{*p} in the best response functions one gets $m^{DN}(\cdot; t^p, t^{*p}) = \frac{d}{1+2a}(\varepsilon - \varepsilon^*), m^{*DN}(\cdot; t^p, t^{*p}) = -\frac{d}{1+2a}(\varepsilon - \varepsilon^*)$. Whether these will be higher or lower than m^{cc}, m^{*cc} depends on the nature of the shocks and the parameters.

Hence, two governments seeking to delegate policy in a manner consistent with their individual rationality (or with their mandate, that is maximising social welfare) would fail to achieve a first best equilibrium. In order to delegate with the scheme that would insure that optimal policies are followed they would need to cooperate at the delegation stage. Alternatively, a supranational institution able to coordinate the two governments on the 'right' institutions would do the same job. However, this is far from the non-cooperative setup one wishes to describe in the first place. If compromises are to be made in terms of allowing for the possibility of binding agreements at the level of governments, it is hard to understand why then wouldn't the governments cooperate directly without any need for delegating policies.

4. Conclusions

The answer of the literature to various inefficiencies associated with policy making, whether at a domestic or international level, has for more than a decade now been: 'Delegate!'. This applied forcefully to designing monetary institutions and took various forms depending on the problem it came to address. In the most prominent example, monetary policy, delegation has been viewed as a panacea for both domestic credibility problems and inefficiencies coming from cross-country spillovers. Given policy externalities, a policy regime where governments cooperate (and commit with respect to the private sectors) is unequivocally Pareto optimal, but there are strong incentives to deviate from it. Interestingly, some simple and intuitive delegation schemes easily mappable into real-life institutions have been proved to 'fix' both these incentives. Examples of this are, *i.a.* the linear inflation contracts proposed by Persson and Tabellini (1995, 1996, 2000), quadratic contracts with targets of Jensen (2000), or inflation targets as in Bilbiie 2000 or Benigno and Genigno (2002, in a New Keynesian setup). In these cases, each government delegates to an independent policy authority by imposing to the latter a certain transfer function. By doing this, the government could in theory induce the delegated authorities to choose the policy instruments such that the desired policy outcomes are obtained. To do that, they *just* need to choose those delegation parameters that insure implementation of the cooperative and commitment optimum when their agents choose policy non-cooperatively and discretionarily, without any need for them to sign binding agreements.

The argument of this paper is that this last phrase is key to this whole literature as it hides an implicit assumption concerning governments being actually able to sign binding agreements (with respect to each other and the private sector). Absent this ability of governments, it is hard to see why they would choose exactly those delegation parameters that 'do the job'. Present this ability of the governments, it is even harder to see why they would need to delegate instead of committing themselves to the optimal policy rules. The way out from this dilemma is, in our view, an explicit modelling of the delegation decision of the governments. We choose to do this by supposing that each government chooses the contracts based on its individual rationality taking into account the agents' choices at a future stage. First, we provide a general solution method and define the new equilibrium concept in a non-parametric model of policymaking with spillovers. Then we present an example from international monetary policy cooperation, where it turns out that the contracts governments would choose will be different, in an intuitive way, from the optimal ones for arbitrary correlations of shocks. The two would be identical only if shocks are absent and/or only state-independent institutions are feasible, but the latter case features again inefficiency. One way for the two to coincide would be to assume cooperation of governments at the delegation stage but that is in contradiction with their assumed inability to commit.

The different welfare implications of the two contracts can be summarised as follows: *optimal contract*s are efficient by construction, but we argue they are not implementable; *credible contracts* are implementable by construction, but they are inefficient. Note that our result is different from the McCallum-Jensen critique concerning closed-economy monetary institutions or more specifically credibility of delegation. Our argument implies that governments will not delegate policy optimally in the first place, let alone sustaining optimal institutions over time.

Our analysis raises a normative question: what could then insure implementation of the 'right' institutions, preserving the non-cooperative assumption about policymaking? One answer would be the creation of a supranational institution that is able to 'coordinate' governments on the optimal contracts at the delegation stage[18]. An alternative would be strengthening the role of some existing supranational institutions (such as the IMF): this reinforces arguments made by Canzoneri and Henderson (1991) in a different setup. There, such an institution helped governments choose, i.e. coordinate on, a best equilibrium among a multiplicity of feasible equilibria. The equilibrium (and hence coordination by the international principal), however, is in terms of policies directly, which seems hard to map into real-life practice. In our context, the supranational institution would help design the appropriate incentive schemes of countries' policy authorities and monitor their implementation over time. While this might seem akin to centralisation or cooperation on policies directly (which would be a solution by assumption), we think it is indeed more realistic to assume that national governments agree to coordinate on some institutional features that to systematically pursue cooperative policies that are not consistent with their incentives. By the presence of such an international institution, sovereignity of policymaking is preserved. Further research is needed in order to analyse the incentives and the design of such supranational institutions, and mechanisms by which they could implement and monitor such globally optimal policy regimes.

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