CRESE
CENTRE DE RECHERCHE
SUR LES STRATÉGIES ÉCONOMIQUES

The rates matter! Assessing the credibility of international corporate tax rate harmonization via cooperative game theory

Alexandre Chirat, Guillaume Sekli

July 2021

Working paper No. 2021 – 04

CRESE
30, avenue de l'Observatoire
25009 Besançon
France
http://crese.univ-fcomte.fr/

UFR SJEPG
Sciences juridiques économiques politiques et de gestion
UNIVERSITÉ DE FRANCHE-COMTÉ

The rates matter! Assessing the credibility of international corporate tax rate harmonization via cooperative game theory[1]

Alexandre Chirat[a], Guillaume Sekli[b]

[a] *Université de Paris-Nanterre — Economix*
[b] *Université de Bourgogne Franche-Comté — CRESE*

Abstract

This article uses the main tools of cooperative game theory, the core of a game and the Shapley value, to tackle the challenge posed by corporate tax harmonization in order to fight profit shifting. More specifically, these tools are applied to provide a counterfactual evaluation and to assess the credibility of Saez and Zucman (2019) proposal to establish a minimum rate at 25% at the G7/G20 level. Based on the empirical data of Tørsløv et al. (2020), our main results are the following. First, at the G7 level, the more countries involved in the agreement, the more efficient it would be. Second, stability of cooperation at the G7 level can be achieved without giving up fairness consideration in the distribution of the surplus. We then extend our application to the G20 and show that these results do not hold anymore. Third, from this case, we conclude that not only the target rate matters in the perspective of international tax cooperation, but also the numbers of participants and their current effective rates.

Keywords: International taxation, Tax cooperation, Profit shifting, Tax havens, Shapley value

JEL codes : E62 - C71 - F42

1. Introduction

On February 19, 2021, G7 leaders argue that they will “strive to reach a consensus-based solution on international taxation by mid-2021 within the framework of the OECD”. This statement is in line with OECD/G20 project on “Base Erosion and Profit Shifting”. Launched in 2013, the project results in reforms proposals based on two pillars (OECD 2020a, 2020b). The first aims at changing the taxation rules to tackle the challenge posed

[1]For valuable comments, we warmly thank Marc Deschamps. We thank Gabriel Zucman for answering our questions. For invaluable help on Maxima software, we are indepted to Sylvain Ferrières.

by the digitalization of the economy. The second aims at establishing a minimum tax rate to multinationals. This second pillar should "reduce the differences in effective tax rates across jurisdictions", which are "one of the main drivers of profit shifting", in order to "reduce multinationals' incentives to shift profit to low-tax jurisdictions" (OECD 2020a, p. 17). Few months ago, President Biden puts forward his Made in America Tax Plan whose similar aim is to "stop profit shifting, and ensure other nations won't gain a competitive edge by becoming tax haven". Biden's administration proposed to raise corporate tax rate up to 28% in the United States and to increase the minimum tax on US corporations to 21% [2]. It also "encourages" other countries "to adopt strong minimum taxes on corporations". On June 5, 2021, G7 finance ministers announced to have reach an agreement on a minimum statutory corporate tax rate of 15%. These various rates often seem to come as a rabbit out of the hat. But this article shows that the level of rate matters! Not all rate levels can ensure credible international tax cooperation.

The 2008 financial crisis had already strengthened the will of G20 members to fight profit shifting. A mean advocated in April 2009 was to put an end to "the era of bank secrecy". Johannesen and Zucman (2014) however documented that the strategy based on exchange of bank information proved rather unsuccessful. The measures taken have led to "a relocation of bank deposits between tax havens but have not triggered significant repatriation of funds" (2014, 89). This failure explains why Saez and Zucman (2019) put forward another strategy, in line with OECD and G20 second pillar, for reforming international taxation. They advocate tax cooperation around a minimum statutory corporate tax rate at the G20 level. With two aims in mind, they propose a rate of 25%. First, such cooperation should prevent tax competition and counter the well-documented downward trend in statutory corporate tax rate (Devereux and Loretz 2013, Keen and Konrad 2013). Second, this minimum corporate tax rate would serve as a benchmark to recover tax deficit due to profit shifting into tax havens as soon as members of the G20 accept to police their multinationals[3]. For year 2015, Tørsløv, Wier and Zucman evaluate the effective corporate tax rate in non-OECD tax havens at 7% (2020b). From their data, we estimate the average effective corporate tax rate in all tax havens at 8.77%[4]. By comparison, the average effective corporate tax rate in OECD countries is 19%. At first glance, their proposal seems attractive to recover tax

[2]The Biden's administration claims wanting to "create a more level playing field between domestic companies and multinationals". See "Fact Sheet: The American Jobs plan", Statements and releases, March 31, 2021, White House.

[3]Devereux and Loretz (2013, 746) distinguish three forms of competition: (*i*) competition for flows of capital, which depend on effective marginal tax rate; (*ii*) competition for flows of firms, which depends on average tax rate; and (*iii*) competition for flows of profits, which depends on statutory tax rates. The reform advocated by Saez and Zucman (2019) addresses this third form of corporate tax competition, which can be defined as horizontal competition between countries for corporate profits. We also do not discuss the issue of vertical competition between jurisdictions of the same country.

[4]See Table A.6 in Tørsløv et al. (2020b).

revenue losses due to profit shifting. First, contrary to the strategy of information exchange, this one does not require the cooperation of tax havens. Second, the mechanism advocated does not imply double taxation.

> "To understand how this could work, let's consider a concrete example. Imagine that, by shifting intangibles and manipulating intragroup transactions, the Italian automaker Fiat had managed to make $1 billion in profits in Ireland, taxed at 5%, and $1 billion in Jersey, one of the Channel Islands, taxed at 0%. There's a problem here: Fiat pays much less tax than it should; much less, in particular, than domestic Italian businesses. We call this a tax deficit. The good news is that nothing prevents Italy from curbing this deficit itself, by collecting the taxes that tax havens choose not to levy. Concretely, Rome could tax Fiat's Irish income at 20%. It could tax its Jersey bounty at 25%. More generally, it could easily impose remedial taxes such that Fiat's effective tax rate, in each of the countries where it operates, equals 25%" (Saez and Zucman 2019, 115-116).

While stressing the administrative viability of their proposal, Saez and Zucman believe that "it is probably too optimistic to expect that all G20 countries will agree to police their own multinationals, join the club of tax collectors of last resort, and apply sanctions against tax havens" (2019, p. 125). This judgment might result from the fact that neither the level of the minimum statutory tax rate they advocate nor the credibility of the agreement is discussed in their book. Assessing that credibility is the aim of this article. If Saez and Zucman advocate that the 25% statutory tax rate acts as a *minimum*, a way to assess the credibility of such an agreement is to evaluate whether G7 countries as a first step, and then G20, have incentive to harmonize their corporate tax rate, so that the 25% corporate statutory tax rate acts as a *common* rate. If it does, these countries would a fortiori have individual and collective interests to consider a 25% corporate statutory tax rate as a minimum one. After reaching an agreement on a common rate, each country of the coalition would indeed be free to rise its own corporate statutory tax rate above 25%, while this rate would continue to serve as a common benchmark to recover tax deficit in tax havens.

The methodological contribution of our article lies in the use of cooperative game theory as a tool to assess the credibility of such a tax harmonization. Cooperative game theory enables studying the process of forming coalitions between players under bidding agreements and then determining rules for allocating payoffs among coalition members. Applied to Saez and Zucman's proposal, cooperative game theory allows to evaluate the tax revenues resulting from the cooperation of all countries of the G7/G20 to test if smaller coalitions of countries have an interest to depart from the grand coalition, whose *raison d'être* is to establish a common corporate tax rate of 25% acting as a benchmark so as to recover tax deficit. We focus on the two main classical tools of cooperative game theory, namely the core of a game (Shapley, 1955) and the Shapley value (Shapley, 1953). These tools can be used to evaluate the stability of cooperation and the fairness of surplus distribution, respectively. By surplus, we refer to the additional tax revenues that are generated by cooperation.

The aim of our work is not to assess the credibility of Saez and Zucman proposal by theoretically determining whether a common statutory corporate tax rate at 25% would be the equilibrium outcome of strategic interactions. Thus, we deliberately exclude strategic interactions and information exchanges between countries from this application. Our modelling strategy aims at reasoning as if the bidding agreement were the equivalent of a social contract *à la Rousseau* between countries forming a coalition (Moulin 2002). In this specific case, the cooperative games that we propose have been built as if G7/G20 members act as a social planner applying Saez and Zucman's reform. Reasoning as if confers a counterfactual value to our modelization, in which we hypothetically envisage tax rate harmonization in situations where some but not all G7/G20 members agree to cooperate[5] . The 2015 data recently provided by Tørsløv, Wier et Zucman (2020a, 2020b) represent the factual, namely the individual amount of tax revenues effectively recovered by G7 countries[6]. Our cooperative games provide the counterfactual since they lead to reason as if the agreement on a common statutory corporate tax rate was implemented.

Our main results are the following. First, at the G7 level, **the more countries involved in the agreement, the more efficient it would be**. For every coalition with two or more countries of the G7 containing the United States, the agreement on a common statutory corporate tax rate of 25% generates a surplus of tax revenues. This result also applies for all coalitions with five or more countries, no matter which countries of the G7 are considered. Second, **stability of cooperation can be achieved without giving up fairness consideration in the distribution of the surplus**. Considering the Shapley value as an allocation rule, we show that the cooperation of G7 countries around a common statutory corporate tax rate of 25% belongs to the core of our game. Because of this second result, Saez and Zucman's proposal seems more credible than expected at first glance at the G7 level. This achievement is the result of a combination of a relatively high rate of 25% and the recovering of tax deficit. The third result indeed reveals that **not only the target rate matters in the perspective of establishing international cooperation, but also the numbers of participants and their current effective rates**. At the G20[7] level, the agreement on a common statutory corporate tax rate of 25% still generate a surplus of tax

[5]The goal of counterfactualizing, as DeMartino recently argues, is indeed "to identify alternative worlds, where things could go very differently from what we might expect". Then, "counterfactual scenarios" could serve as "instruments for managing better in a world that we can't ultimately know, and that we can influence but never control" (2020, 9).

[6]Raw data used in the article are presented in Appendix 1. Data have been precisely built to "be used to quantify the tax revenues that individual countries could gain under different tax reform scenarios" (Tørsløv and al. 2020a, 4).

[7]If we refer to the G20, we compute our games for 16 countries only. Data for Argentina, Indonesia and Saudi Arabia are not available. Moreover, we do not consider the European Union as a single entity.

revenues. But the principle according to which the more countries involved in the agreement, the more efficient it would be, does not hold anymore. The stability of cooperation under such a common corporate tax rate cannot be reconciled with fairness consideration (in the sense of Shapley value). The Shapley value is not a core allocation because increasing the number of coalition members generates a dilution effect in the distribution of recovered tax deficits.

To the best of our knowledge, this article represents the first attempt to apply cooperative game theory, on an empirical basis, to international tax cooperation issues. Despites recognizing that international tax cooperation is "a natural response" to limit the effect of tax competition (Gresik 2001, 801) and that this "natural appeal" will generally be more efficient than decentralized decision-making (Keen and Konrad 2013, 288, 317), the literature dealing with international corporate taxation in a context of globalization have focused on competition rather than cooperation[8]. The main explanation of this stance is that international tax coordination seems an incredible or even an unthinkable scenario. Wilson argues that "at the international level, there do not exist strong institutions for coordinating the activities of sovereign nations" (1999, 277). Devereux and Loretz add that "tax cooperation so as to reduce corporate tax competition has proved to be difficult to implement on international basis" so that the large countries should seek to "improve attractiveness of the country as a corporate location" in order to be able to maintain relatively high tax rate and revenues (2013, 765). Keen and Konrad explain that tax coordination "requires the absence of asymmetric information and it typically requires full commitment", so that agreements should be written "prior to any possible unilateral action by which a single player can tilt the cooperative outcome in their own favor"[9] . They conclude on this basis that tax cooperation requires "more than one can expect" in an "international context with sovereign countries" (2013, 287). But it is precisely because cooperation seems unlikely that we propose to account for it in a counterfactual and static way rather than basing it on a model of strategic interactions. And in any case, the fact that that tax coordination requires full commitment from sovereign countries is not *per se* an obstacle to its study. Indeed, cooperative game theory is a relevant starting point to help resolving the main problem identified concerning the economic analysis of international tax coordination, which is "to explain what makes commitment feasible and credible at the stage when countries commit on their timing" (Keen and Konrad 2013, 280).

To this aim, we provide preliminaries on cooperative game theory and introduce the

[8]The main result of the theoretical literature on tax competition, under the assumption of (perfect) mobility of capital, is that small open countries tend to lower their statutory tax rate to enlarge their tax base (Zodrow et Mieszkowski 1986, Wilson 1986). These models provide a good approximation of the actual behavior of countries that are called tax havens. Tax haven, which are generally little countries (Dharmapala and Hines 2009), cannot attract activities requiring physical location, whereas they easily attract profits.

[9]Hence the importance of the notion of fairness.

games modelling Saez and Zucman's scenario of reform (Section 2). Next we compute our games for G7 countries and presents the main results (Section 3). We show that even if some countries of the G7 have current statutory and effective corporate tax rate superior to 25%, this latter could act as a common rate acceptable for all G7 members because of surplus generated (Section 3.1). The credibility and stability of cooperation depend on the various allocation rules of the surplus of tax revenue and tax deficit recovered that could be implemented. We consider the most studied one, because of its properties in terms of efficiency and fairness, namely the Shapley value (Section 3.2). We then extend this application to the G20 (Section 4). We finally echo currents events by providing quantitive evaluations based on Biden's administration plan to raise corporate tax rate to 28% and set a minimum rate on US multinationals at 21% on the one hand and G7 announcement on a minimum rate of 15% on the other. We compute our games under these values to provide comparison with previous results (Section 5). In conclusion, we sum up the main results and discuss some limitations of our work that should be overcome in future works.

2. A cooperative game theoretic approach

In this section, we first present the framework of cooperative game theory. We then illustrate how tax cooperation can be formalized with cooperative game theory.

2.1. Preliminaries on cooperative games

A cooperative game is a pair (N, v) where $N = \{1, ..., n\}$ is a finite set of n players and v is a characteristic function which assigns a worth $v(S)$ to each coalition $S \subseteq N$, and such that $v(\varnothing) = 0$. The worth of a coalition is the payoff that members of the coalition S can secure by themselves. In other words, it represents "the best outcome that each subset of the participants ('players') can achieve being unaided" (Shapley and Shubik 1967, p. 92). With n players, a cooperative game is composed of 2^n potential coalitions (including the empty coalition). The coalition N of all players is called the grand coalition and is considered as actually formed, the others coming from counterfactual scenarios.

An *allocation* for a game (N, v) is a payoff vector $x = (x_1, ..., x_n)$ which assigns a payoff $x_i \in \mathbb{R}$ to each player $i \in N$ in order to reflect her participation to game (N, v). It is efficient if $\sum_{i \in N} x_i = v(N)$. The *core* of game (N, v) is the set $C(N, v)$ of all efficient allocations x such that no coalition of players S gets a total payoff $\sum_{i \in S} x_i$ smaller than its worth $v(S)$, that is to say not smaller than what it can secure for its members. Formally:

$$C(N, v) = \left\{ x \in \mathbb{R}^N : \sum_{i \in S} x_i \geq v(S), S \subseteq N, \sum_{i \in N} x_i = v(N) \right\}.$$

The core can be empty. If x is a core allocation, then it is in the interest of no coalition of players to split from the grand coalition. Hence the grand coalition can be considered as stable if its members are paid according to such a core allocation. Stability is sometimes incompatible with fairness considerations.

The Shapley value of a game is traditionally seen as a fair allocation rule. It is efficient, additive (the Shapley value in the sum of 2 games is the sum of the Shapley values in these 2 games), assigns a null payoff to any player whose marginal contributions to coalitions are null, and assigns an equal payoff to players characterized by identical marginal contributions to coalitions. More specifically, the Shapley value is uniquely characterized by these four properties or axioms, and assigns to a player i in a game (N, v) a payoff $Sh_i(N, v)$ which is a weighted average of all her marginal contributions. If we denote the cardinal of coalition S by $s = |S|$, then the Shapley value is formally:

$$Sh_i(N,v) = \sum_{S \subseteq N \setminus \{i\}} \frac{s!(n-s-1)!}{n!} \big(v(S \cup \{i\}) - v(S) \big), \quad \forall i \in N.$$

2.2. The games induced by tax harmonization

Currently, every country forming the G7 discretionary determines its statutory corporate tax rate. Mainly because of profit shifting, there is a divergence between the tax revenues effectively collected and the application of statutory rates to the reported corporate profits. For this reason, Tørsløv, Wier and Zucman (2020) calculated an effective corporate tax rate for each country that differs in various extents from statutory rate (Appendix 1). With tax cooperation, every country abandons either its discretionary power to set its own statutory rate (common rate) or to set it without supranational constraint (minimum rate). If tax cooperation is implemented, one stake concerns the terms of the agreement related to the sharing of the surplus generated by cooperation. Another concerns the tax deficit that could be recovered. Such a problem of tax cooperation could be described by the sextuplet $(N, (\pi_i, t_i, \pi_i^L)_{i \in N}, t, \bar{t})$ where:

- $N = \{1, ..., n\}$ represents the countries of the G7 or G20.
- π_i represents the corporate reported profits in country i, for each $i \in N$.
- t_i represents the effective corporate tax rate in country i, for each $i \in N$.
- π_i^L represents the profit shifts to tax havens from country i, for each $i \in N$.
- t represents a common corporate statutory tax rate — in our case 25%.
- $\bar{t}$ represents the average statutory corporate tax rate in tax havens — in our case, 8.77%.

It should be clear that t_i can be more or less than t for a given country i and that $\bar{t}$ is less than t. We propose two different games to model the first part of the economic problem posed by Saez and Zucman's proposal. The first one is a constrained game whereas the second opens the possibility of cooperation to recover tax deficit but without applying the common rate if unfavorable for some countries. The first game (N, v) assigns to each one-country coalition its current individual tax revenue, the corporate reported profits in one country multiplied by its effective tax rate (the factual). For each coalition S with two or more countries, it assigns the sum of the corporate reported profits in each country of the coalition multiplied by the common corporate statutory taxe rate (counterfactuals). Formally, the worth $v(S)$ is:

$$v(S) = \begin{cases} \pi_i t_i & \text{if } s = 1, \\ \left(\sum_{i \in S} \pi_i\right) t & \text{if } s > 1. \end{cases}$$

This worth $v(S)$ is the tax revenue that S could achieve if the profits reported in its members are taxed at the common rate t, except for singletons ($s = 1$) for which the revenue is calculated from the current domestic effective rate. In other words, we assume that as soon as two countries agreed to form a coalition, they have to adopt the common rate t. As an alternative to game (N, v), we introduce a game (N, v^*). It consists in considering the maximum payoffs (tax revenues) that each coalition could pretend to with or without implementing the common rate t. Singletons are treated as in (N, v). For coalitions S with two or more countries, they apply the common rate t only if it leads to a total revenue at least as large as what its members would obtain from their respective current domestic rate. Formally, the worth $v^*(S)$ is:

$$v^*(S) = \begin{cases} \pi_i t_i & \text{if } s = 1, \\ \max\left\{\left(\sum_{i \in S} \pi_i\right) t; \sum_{i \in S} \pi_i t_i\right\} & \text{if } s > 1. \end{cases}$$

The game (N, v^*) is an interesting complement to (N, v) for two reasons. First, it better takes the rationality of coalitions of country into account. By introducing a maximization, game (N, v^*) models a situation where the total revenue of coalition of countries cannot decrease if a new country joins the coalition. In other words, (N, v^*) is monotonic game (see Appendix 4 in which extra properties are provided). Thus, the meaning of cooperation depends on the value attributed to t. If it is relatively low, countries cooperate without setting a common rate but only to define a benchmark rate to recover tax deficit. If it is high enough, games (N, v) and (N, v^*) coincide. Countries cooperate by setting a common rate that also serve as a benchmark rate to recover tax deficit. Second, the difference between $v^*(S)$ and $v(S)$ immediately provides the tax revenue losses generated if S accepts the common statutory corporate tax rate t (Appendix 2).

As a reminder, one of the two main aims of the reform advocated by Saez and Zucman is to provide a benchmark to recover profit losses due to profit shifting in tax havens. This recovering of tax deficit is modeled by a third game (N, w). For singletons, the worth $w(S)$ is equal to zero (the factual). Without a coalition of countries signing a bidding agreement to fight against profit shifting into tax haven, it seems unrealistic that a country manage to police its multinationals[10]. We apply the same reasoning for all coalitions except the grand one. Indeed, any country could have incentive to free ride. If for instance only six of the seven G7 countries agree on policing their multinationals using the common rate t as a benchmark, the free-riding country would potentially attract flow of firms, capitals and profits. We believe that unanimity is required for a credible recovering of tax deficit, which translates into a game such that only the worth of the grand coalition is different from zero. The latter amount is equal to the sum of profit losses of each G7 countries multiplied by the difference between the common statutory corporate tax rate t and the average tax rate in fiscal havens $\bar{t}$. Formally, the worth $w(S)$ is:

$$w(S) = \begin{cases} 0 & \text{if } s < n, \\ \sum_{i \in N} \pi_i^L (t - \bar{t}) & \text{otherwise.} \end{cases}$$

3. Application to G7

3.1. Computation

As a first step, we calculate the worth $v(S)$, $v^*(S)$, and $w(S)$ for the G7 case, that is to say the tax revenues of the 127 potential coalitions[11] . The results are presented in Appendix 2. To do that, we only needed the empirical data of Table 1 below, extracted from Tørsløv and al. (2020b), and to set $t = 0.25$.

Table 1: The data for G7

G7	USA	JAP	GER	FRA	UK	ITA	CAN
t_i(effective corporate tax rate in %)	0.21	0.26	0.11	0.27	0.17	0.18	0.35
π_i(corporate reported profits in billion $)	1889	634	553	188	425	212	143
π_i^L (profit shift to tax havens in billion $)	142	28	55	32	62	23	17

These raw data are worth a comment. The corporate profits of firms in the United States represents 46.7% of corporate profits reported by corporations of the G7 and its

[10]If the French government only decide to police its multinationals while other governments of the G7 do not, French population would be prone to criticize its government for penalizing its multinationals.

[11]The worth of the empty coalition is zero.

current effective corporate tax rate is 21%. That explains a first important result. For every coalitions with two or more countries containing the United States, the agreement on a common statutory corporate tax rate of 25% would generate a surplus, that is to say more tax revenues compared to the sum of individual current tax revenues of countries participating in the coalition. This counterfactual assessment leads to conclude that the government of the United States could assume a leadership in the perspective of a real agreement.

On the contrary, Japan, France and Canada have current effective corporate tax rates above the common statutory rate of 25%. That explains the second important result. Coalitions experiencing a loss under the bidding agreement, loss quantified by column $v^*(S)-v(S)$ in Appendix 2, always contains some of these countries. For instance, if Canada, France, and Japan cooperate (the coalition nº 50 in Appendix 2), the loss of tax revenues would amount to $24.4 billion of dollars. We can however note that among the 120 coalitions with two or more countries, only 7 generate a loss of tax revenues. We also observe that no coalition of five or more countries, no matter which countries are considered, experiences a loss under the bidding agreement on a common rate at 25%. This is the first main result.

Result 1. *The more G7 countries involved in this agreement, the more efficient it would be.*

Another result is that the grand coalition of all G7 countries would generate, under the bidding agreement, an amount of tax revenues equal to $1011 billion. Compared to what they currently generate separately (the sum of the worth of singletons), the agreement generate a surplus that amounts to $177.42 billion. The existence of such a surplus is a necessary condition, though not a sufficient one, to conceptualize a stable allocation of payoffs between members of the grand coalition. Another information is noteworthy. We calculated that the common statutory corporate tax rate should be at least 20% to ensure that the grand coalition generates a surplus compared to the sum of current individual tax revenues. This means that the profits generating by the participation of the United States, whose current effective rate is 21%, are not necessary to generate a surplus. In light of this result, the rate of 15% advocated by G7 ministers of finance, yet only as a benchmark to recover tax deficit, is not a credible option as a common rate.

We also compute the game (N, w) in which we assume that cooperation between all G7 members is required to recover tax deficit and prevents free riding. The amount of tax deficit recovered if the members of the grand coalition police their multinationals is $58.15 billion. Almost 40% comes from US multinationals. This second surplus is also taken into account in our work on the Shapley value as an allocation rule to share the whole surplus of tax cooperation.

3.2. The Shapley value

We computed the Shapley value of game (N, v) for $t = 25\%$ (Table 2, Column 2). The resulting allocation does not belong to the core of the game since it assigns less to Japan and Canada than their worth as singletons. The same applies to game (N, v^*) (Table 2, Column 3). On the contrary, the United states, because of hosting a large share of corporate profits reported in G20 countries, and Germany, because of a current effective rate (11%) far below the common statutory corporate rate (25%), are the main beneficiaries if this allocation rule is used. From the case of Germany, we observe that, in its application to international fiscal cooperation, the Shapley value benefits more countries which are currently the more involved in tax competition. In other words, it provides these countries substantial incentives in favor of cooperation rather than competition.

Table 2: The Shapley value for G7 (in billion $)

	1	2	3	4	5
	$v(\{i\}) = v^*(\{i\})$	$Sh(N, v)$	$Sh(N, v^*)$	$Sh(N, w)$	$Sh(N, v^* + w)$
USA	369.69	463.88	463.09	8.31	471.39
JAP	164.84	163.78	164.67	8.31	172.98
GER	60.83	129.57	128.78	8.31	137.08
FRA	50.76	51.85	52.61	8.31	60.92
UK	72.25	104.81	104.01	8.31	112.32
ITA	38.16	54.75	54.27	8.31	62.57
CAN	50.05	42.36	43.57	8.31	51.88
Total	833.58	1011	1011	58.15	1069.15

The Shapley value, as an allocation rule, does not ensure the stability of the cooperation between the G7 countries for both games (N, v) and (N, v^*). Between $Sh(N, v)$ and $Sh(N, v^*)$, the difference is tiny, but not marginal. The Shapley value of (N, v^*) attributes a higher allocation for countries having current effective corporate tax rate higher than 25%. The explanation lies in considering the maximum payoffs that each coalition could pretend with or without implementing the common rate in game (N, v^*). In the rest of the article, we consider only the Shapley value of this latter, assuming that it provides a better benchmark. For each country i, the difference between $Sh_i(N, v^*) - v^*(\{i\})$ evaluates the gain or loss between the payoffs assigned by the Shapley value and the current effective tax revenues of country i. The payoff assigns to Canada and Japan should respectively be $6.48 and $0.17 billion higher to just equal their current domestic tax revenues.

Since an agreement between G7 countries would foster the recovering of their tax deficit, we computed the Shapley value of the game (N, w). With an average tax rate of 8.77% in tax havens and a common statutory corporate tax rate of 25%, we previously showed that G7 countries could recovered $58.15 billion in tax deficit. Since we assume that such a recovering is credible only if all G7 countries would be willing to cooperate, the Shapley value of the game (N, w) is equivalent to an equal division of the tax deficit recovered. It assigns \$8,31 billion to each G7 country (Table 2, Column 4). From the additivity of the Shapley value, we then deduced $Sh_i(N, v^* + w)$ (Table 2, Column 5). If we compare the amount assigned by this Shapley value to the individual worth of country in game (N, v^*+w), which is equal to $v^*(\{i\})$ since $w(\{i\})$ is equal to zero, every country receives more than its current tax revenues. Furthermore, using a program on Maxima, we prooved that the Shapley values $(N, v^* + w)$ belongs to the core of games $(N, v^* + w)$ for $t = 0.25$. This is the second main result.

Result 2. *Stability of cooperation between G7 countries can be achieved without giving up fairness consideration in the distribution of the surplus.*

The Shapley value of game (N, w), because of being a symmetric game, is equivalent to an equal division rule. This later is also a common allocation rule on cooperative game theory (Van den Brink, 2007). Contrary to the Shapley value, it does not consider the marginal contributions of countries to put the emphasis on solidarity between members of a coalition. One might wonder why the United States, who would contribute to recover \$23 of the \$58 billon of tax deficit, would accept such an allocation rule (Table 3). Some arguments could be put forward. First and foremost, we explain that the fight against profit shifting in tax havens requires the collaboration of all members of the grand coalition. Each country implementing the common rate as a benchmark to recover losses due to profit shifting would benefit each members of the coalition. An equal division of tax deficit is moreover prone to foster both cooperation and commitment. Second, the potential feeling in the US to be aggrieved in the short run could be compensated by understanding that, as soon as the playing field has been leveled in terms of statutory corporate tax rate, it might benefit in the longer run its greater ability to attract flows of capital and firms. Third, beyond a principle of cooperation, the equal division appear relevant in international context since it echoes the principle that the voice of one sovereign country equal another.

Table 3: Allocation of profit recovered (in billion \$)

	1	2
	$Sh(N, w)$	Profit recovered by country i
USA	8.31	23.05
JAP	8.31	4.52
GER	8.31	8.91
FRA	8.31	5.21
UK	8.31	9.98
ITA	8.31	3.65
CAN	8.31	2.80
Total	58.15	58.15

4. Application to G20

In line with Saez et Zucman's proposal, we extend our application at the G20 level. Since data are not available for Argentina, Indonesia and Saudi Arabia (Appendix 1) and since we do not consider the European Union as a single entity to avoid duplication with its members, we take 16 countries into account. We computed our games with t equal to 25%, which is pratically possible through a computer program (on Maxima) since there are $2^{16} - 1$ non empty coalition. Results are presented in Table 4.

Table 4: The Shapley value for G20 (in billion $)

Countries	$v^*(\{i\})$	$Sh(N, v^*)$	$Sh(N, w)$	$Sh(N, v^* + w)$	$Sh(N, v^* + w) - (v^* + w)(\{i\})$
Australia	53.7	47.64	4.9	52.54	-1.16
Canada	50.05	39.16	4.9	44.06	-5.99
France	50.76	49.44	4.9	54.34	3.58
Germany	60.83	134.93	4.9	139.83	79
Italy	38.16	53.88	4.9	58.78	20.62
Japan	164.84	161.17	4.9	166.07	1.23
Korea	44.64	62.7	4.9	67.6	22.96
Mexico	39	80.28	4.9	85.18	46.18
Turkey	12.78	52.39	4.9	57.29	44.51
UK	72.25	105.83	4.9	110.73	38.48
USA	396.69	469.05	4.9	473.95	77.26
Brazil	54.8	69.5	4.9	74.4	19.6
China	413.8	512.2	4.9	517.1	103.3
India	37.6	92.08	4.9	96.98	59.38
Russia	40.6	72.22	4.9	77.12	36.52
South Africa	19	21.11	4.9	26.01	7.01
Total	1549.5	2023.58	78.4	2101.98	

For a common statutory corporate tax rate of 25%, the grand coalition of the G16 countries would generate, under the bidding agreement, an amount of tax revenues equal to $2023.58 billion. Compared to what they currently generate, the sum of the worth of singletons, the agreement would generate a first surplus of $474.08 billion. However, tax deficit recovered, contrary to what happened at the G7 level, does not ensure stability of the cooperation if the Shapley value is used as an allocation rule. $Sh_i(N, v^* + w)$ is less than $(v^* + w)(\{i\})$ for two countries, namely Australia and Canada. The increase from 7 to 16 countries yields a dilution effect in the distribution of recovered tax deficits.

We also computed our games for t equal to 21% and 28%, namely the values mentioned in Biden's tax plan (Appendix 3). For t equal 28%, the payoff attributed by the Shapley value to Canada is still inferior to its worth as a singleton. Ensuring a stable cooperation at the G16 level around a common statutory corporate tax rate with the Shapley value as an allocation rule does not ensure cooperation for all statutory corporate tax rate under 28%. But running our program, we did not find any value of t, even higher than 28%, such that the corresponding Shapley value is a core allocation at the G16 level. The main explanation lies in the fact that some G20 countries, in particular Germany, Turkey and India, have current effective corporate tax rate so low, respectively 11%, 6% and 10%, that their marginal contributions in case of an agreement on a common rate would mechanically be relatively high, as illustrated by the differences between column $v^*(\{i\})$ and $Sh_i(N, v^*)$ in Table 4. This lead to the third main result.

Result 3. *Not only the target rate matters in the perspective of establishing international cooperation, but also the numbers of participants and their current effective rates.*

Even if the Shapley value is not a core allocation at the G16 level, the core is non-empty if the common tax rate is high enough. This is a consequence of a general result provided in Appendix 4.

5. Tax rates matters!

The results at the G20 level invites to reconsiderate the case of the G7 for other value attributed to t. We computed our games for a common statutory corporate tax rate $t = 0.28$ and 0.21 (Table 5). In the scenario with $t = 0.28$, the surplus generated by the grand coalition of G7 members compared to the sum of individual effective tax revenues would amount to $298.74 billion. The tax deficit that could be recovered in the case of 28% acting as a benchmark would amount to $69 billion instead of $58 billion at 25%. As an allocation rule that is judged both efficient and fair, we goes on computing the Shapley value for our game $(N, v^* + w)$ for t equals 28%. Then we quantify the global tax revenues generated by a potential agreement, by making the difference, for each G7 country, between the payoff assigned by the Shapley value and its worth as a singleton. An agreement is credible, in the sense that the Shapley value of $(N, v^* + w)$ belong to its core.

Since President Biden's plan is however calibrated on a minimum tax on US multinationals equal to 21%, such a rate seems politically more credible in a near future. That is why we compute our games for a common statutory corporate tax rate $t = 0.21\%$. In this scenario, the surplus generated by the grand coalition would amount to $15.66 billion. The tax deficit that could be recovered in the case of 21% acting as a benchmark would amount to $43 billion. But applying the Shapley value as an allocation rule, Japan and Canada would respectively loose $9 and $3 billion of tax revenues compared to their current situation. As a consequence, the Shapley value does not belong to the core of the game $(N, v^* + w)$ for $t = 21\%$ — whereas it does for $t = 25\%$ and 28%. These differences reminds us of a simple fact. The targeted rate in the perspective of reaching a credible international cooperation to fight profit shifting cannot be chosen randomly. The rate critically matters!

Table 5 : Indiviudal tax revenues surplus (in billions of $)

	$Sh_i(N, v^* + w) - (v^* + w)(\{i\}))$		
t	21%	25%	28%
USA	8.13	74.70	127.07
JAP	-9.06	8.14	27.44
GER	33.05	76.25	95.22
FRA	1.83	10.16	18.71
UK	17.17	40.07	55.83
ITA	11.47	24.41	34.54
CAN	-3.11	1.83	8.80
Total	59.48	235.57	367.62

On June 5, 2021, G7 finance ministers announced to have reached an agreement on a minimum statutory corporate tax rate of 15%. Such a low rate would not ensure the stability of the coalition if considered as a common statutory corporate tax rate. The preceding insights thus lead to conclude that its aims could only be to recover tax deficits, but on an individual basis between G7 members. To go on providing quantitive evaluation, Table 6 summarizes the amount of tax deficit that would be recovered by each G7 countries for the different rates mentioned above as well as the value in case of an egalitarian sharing. With a minimum corporate tax rate on 15%, G7 countries would recover $22.31 billions of dollars in 2015.

Table 6: Tax deficit recovered by each country (in billions of $)

Countries	15%	21%	25%	28%
USA	8.85	17.37	23.05	27.32
JAP	1.73	3.41	4.52	5.36
GER	3.42	6.71	8.91	10.56
FRA	2	3.92	5.20	6.17
UK	3.83	7.52	9.98	11.82
ITA	1.41	2.78	3.68	4.37
CAN	1.07	2.11	2.80	3.31
Total	22.31	43.82	58.14	68.91
Equalitarian sharing	3.19	6.26	8.31	9.84

6. Conclusion

At the G7 level, the main results of this exploratory study are the following ones. First, for every coalitions with two or more countries containing the United States, the agreement on a common statutory corporate tax rate of 25% yields a surplus of tax revenues. Second, no coalition of five or more countries, no matter which countries are considered, experiences a loss under such a bidding agreement. Third, if the Shapley value is considered as an allocation rule, the cooperation of G7 countries around a common statutory corporate tax rate of 25% is stable as soon as tax deficits recovered are incorporated. These results have been computed only for the year 2015 (Tørsløv and al. 2020). Thus, the empirical next step is to replicate our approach for other years. If Saez and Zucman's proposal is credible at the G7 level, it is not at the G20 level. In this case, the stability of cooperation under a common corporate tax rate is no possible under the Shapley value. The two main explanations are the extreme divergencies between effective corporate tax rates and the dilution effect in the distribution of recovered tax deficits. A theoretical next step of our research will be to reflect on the Owen value (Owen, 1977) as an alternative allocation rule. It is a generalization of the Shapley value that takes into account a pre-existing organization of countries into mutually disjoint sub-coalitions. These sub-coalitions would aim to reflect proximities between some countries of the G20, such as the proximities of their current effective corporate tax rate as well as their commercial or geopolitical affinities. Furthermore, other questions in the case of a bidding agreement and full committment are interesting to investigate. An example is the question of how to use the surplus generated by the grand coalition. It could be used for instance to finance international public goods, such as environnmental issues.

To conclude, we would like to comment on some points regarding our methodology. A challenge addressed to our modelization is that the implementation of tax cooperation on an agreement on a statutory corporate rate tax would have dynamic effects that are not apparent in our results. In fact, our applications provide a static evaluation of the consequences of an agreement. But since this particular agreement aimed at leveling the playing field and providing a benchmark in order to recover profit losses due to profit shifting, there are good reasons to believe that potential profit shifting generated by this agreement will be in favor of G7 countries and at the expenses of tax havens. Indeed, if the reform is implemented, knowing that its aim is to provide a benchmark for policing multinationals, it will eliminate the discrepancy in statutory corporate tax rate generating profit shifting. This can be done by providing microeconomic foundations to our cooperative games, i.e introducing a model of tax competition, the equilibrium of which being the basis of a tax cooperative game but this is clearly out of the scope of our article.

References

DeMartino, G.F (2020). The confounding problem of the counterfactual in economic explanation, *Review of Social Economy*, 1-11

Devereux, M.P., Loretz, S. (2013). What do we know about coporate tax competition?, *National Tax Journal*, 66(3), 745-774

Dharmapala, D., Hines Jr, J.R. (2009). Which countries become tax havens?, *Journal of Public Economics*, 93(9-10), 1058-1068

Gresik, T.A (2001). The taxing task of taxing transnationals, *Journal of Economic Literature*, 39(3), 800-838

Johannesen, N., Zucman, G. (2014). The end of bank secrecy? An evaluation of the G20 tax haven crackdown. *American Economic Journal: Economic Policy*, 6(1), 65-91.

Keen, M., Konrad, K.A. (2013). The theory of international tax competition and coordination, *Handbook of Public Economics*, 5, 257-328

Moulin, H. (2002). An appraisal of cooperative game theory, 80-95. In *Game theory and Economic Analysis; a quiet revolution in economics.* C. Schmidt(ed). New-York, Routledge.

OECD (2020a). *Tax challenges arising from digitalization — Economic impact assessment* OECD/G20 Base Erosion and Profit Shifting Project

OECD (2020b). *Tax challenges arising from digitalization — Report on pillar two blueprint.* OECD/G20 Base Erosion and Profit Shifting Project

Owen, G. (1977). Values of games with A priori unions. *Mathematical Economics and Game Theory.* Ed. by R. Henn and O. Moeschlin. Berlin 1977, 76-88.

Peleg, B., Sudhölter, P., (2003). Introduction to the theory of cooperative games. *Kluwer Academic Publishers.*

Saez, E., Zucman, G. (2019). *The triumph of injustice: How the rich dodge taxes and how to make them pay.* WW Norton & Company.

Shapley, L.S. (1953). A value for n-person games, In *Kuhn and A. Tucker, Contribution to the Theory of Games*, vol.II, Princeton, p.303-317

Shapley, L.S. (1955). Markets as cooperative games. *RAND Corporation Paper*, Santa Monica, California, 1-5.

Shapley, L.S., Shubik, M. (1967). Owernship and the production function. *The Quarterly Journal of Economics*, 81(1), 88-111

Tørsløv, T., Wier, L., Zucman, G. (2020a). The missing profits of nations, *Working Paper*, 22 Avril 2020

Tørsløv, T., Wier, L., Zucman, G. (2020b). The missing profits of nations, *Online Appendix*, 22 Avril 2020

Van den Brink R., (2007). Null or nullifying players: the difference between the Shapley value and equal division solutions. *Journal of Economic Theory*, 136, p.767-775

Wilson, J.D. (1986). A theory of interregional tax competition. *Journal of Urban Economics*, 19(3), 296-315

Wilson, J.D. (1999). Theories of tax competition. *National Tax Journal*, 269-304

Zodrow, G.R., Mieszkowski, P. (1986). Pigou, Tiebout, property taxation, and the underprovision of local public goods. *Journal of Urban Economics*, 19(3), 356-370

Appendix

Appendix 1 : Data 2015 for the G20 countries (in billion $)

Countries	Effective corporate taxe rate (t_i)	Reported corporate profit (π_i)	Total profit shift to tax haven (π_i^L)
Australia	30%	179	12.00
Canada	35%	143	17.23
France	27%	188	32.08
Germany	11%	553	54.90
Italy	18%	212	22.70
Japan	26%	634	27.85
Korea	18%	248	4.44
Mexico	12%	325	12.12
Turkey	6%	213	4.61
UK	17%	425	61.50
USA	21%	1889	142.04
Brazil	20%	274	13.24
China	20%	2069	54.64
India	10%	376	8.75
Russia	14%	290	11.35
South Africa	25%	76	3.83
Argentina	No data	No data	No data
Saudi Arabia	No data	No data	No data
Indonesia	No data	No data	No data
Source: Tørsløv et al. (2020b)	Appendix A.6	Appendix A.6	Appendix C.4

Appendix 2: Results of (N, v), (N, v^*) for G7 and $t = 25\%$

Number	Coalition S	$v(S)$	$v^*(S)$	$v^*(S) - v(S)$
1	{USA}	396.69	396.69	0
2	{JAP}	164.84	164.84	0
3	{GER}	60.83	60.83	0
4	{FRA}	50.76	50.76	0
5	{UK}	72.25	72.25	0
6	{ITA}	38.16	38.16	0
7	{CAN}	50.05	50.05	0
8	{USA,JAP}	630.75	630.75	0
9	{USA,GER}	610.5	610.5	0
10	{USA,FRA}	519.25	519.25	0
11	{USA,UK}	578.5	578.5	0
12	{USA,ITA}	525.25	525.25	0
13	{USA,CAN}	508	508	0
14	{JAP,GER}	296.75	296.75	0
15	{JAP,FRA}	205.5	215.6	10.1
16	{JAP,UK}	264.75	264.75	0
17	{JAP,ITA}	211.5	211.5	0
18	{JAP,CAN}	194.25	214.89	20.64
19	{GER,FRA}	185.25	185.25	0
20	{GER,UK}	244.5	244.5	0
21	{GER,ITA}	191.25	191.25	0
22	{GER,CAN}	174	174	0
23	{FRA,UK}	153.25	153.25	0
24	{FRA,ITA}	100	100	0
25	{FRA,CAN}	82.75	100.81	18.06
26	{UK,ITA}	159.25	159.25	0
27	{UK,CAN}	142	142	0
28	{ITA,CAN}	88.75	88.75	0
29	{USA,JAP,GER}	769	769	0
30	{USA,JAP,FRA}	677.75	677.75	0
31	{USA,JAP,UK}	737	737	0
32	{USA,JAP,ITA}	683.75	683.75	0
33	{USA,JAP,CAN}	666.5	666.5	0
34	{USA,GER,FRA}	657.5	657.5	0
35	{USA,GER,UK}	716.75	716.75	0
36	{USA,GER,ITA}	663.5	663.5	0

Number	Coalition S	$v(S)$	$v^*(S)$	$v^*(S) - v(S)$
37	{USA,GER,CAN}	646.25	646.25	0
38	{USA,FRA,UK}	625.5	625.5	0
39	{USA,FRA,ITA}	572.25	572.25	0
40	{USA,FRA,CAN}	555	555	0
41	{USA,UK,ITA}	631.5	631.5	0
42	{USA,UK,CAN}	614.25	614.25	0
43	{USA,ITA,CAN}	561	561	0
44	{JAP,GER,FRA}	343.75	343.75	0
45	{JAP,GER,UK}	403	403	0
46	{JAP,GER,ITA}	349.75	349.75	0
47	{JAP,GER,CAN}	332.5	332.5	0
48	{JAP,FRA,UK}	311.75	311.75	0
49	{JAP,FRA,ITA}	258.5	258.5	0
50	{JAP,FRA,CAN}	241.25	265.65	24.4
51	{JAP,UK,ITA}	317.75	317.75	0
52	{JAP,UK,CAN}	300.5	300.5	0
53	{JAP,ITA,CAN}	247.25	253.05	5.8
54	{GER,FRA,UK}	291.5	291.5	0
55	{GER,FRA,ITA}	238.25	238.25	0
56	{GER,FRA,CAN}	221	221	0
57	{GER,UK,ITA}	297.5	297.5	0
58	{GER,UK,CAN}	280.25	280.25	0
59	{GER,ITA,CAN}	227	227	0
60	{FRA,UK,ITA}	206.25	206.25	0
61	{FRA,UK,CAN}	189	189	0
62	{FRA,ITA,CAN}	135.75	138.97	3.22
63	{UK,ITA,CAN}	195	195	0
64	{USA,JAP,GER,FRA}	816	816	0
65	{USA,JAP,GER,UK}	875.25	875.25	0
66	{USA,JAP,GER,ITA}	822	822	0
67	{USA,JAP,GER,CAN}	804.75	804.75	0
68	{USA,JAP,FRA,UK}	784	784	0
69	{USA,JAP,FRA,ITA}	730.75	730.75	0
70	{USA,JAP,FRA,CAN}	713.5	713.5	0
71	{USA,JAP,UK,ITA}	790	790	0
72	{USA,JAP,UK,CAN}	772.75	772.75	0
73	{USA,JAP,ITA,CAN}	719.5	719.5	0

Number	Coalition S	$v(S)$	$v^*(S)$	$v^*(S) - v(S)$
74	{USA,GER,FRA,UK}	763.75	763.75	0
75	{USA,GER,FRA,ITA}	710.5	710.5	0
76	{USA,GER,FRA,CAN}	693.25	693.25	0
77	{USA,GER,UK,ITA}	769.75	769.75	0
78	{USA,GER,UK,CAN}	752.5	752.5	0
79	{USA,GER,ITA,CAN}	699.25	699.25	0
80	{USA,FRA,UK,ITA}	678.5	678.5	0
81	{USA,FRA,UK,CAN}	661.25	661.25	0
82	{USA,FRA,ITA,CAN}	608	608	0
83	{USA,UK,ITA,CAN}	667.25	667.25	0
84	{JAP,GER,FRA,UK}	450	450	0
85	{JAP,GER,FRA,ITA}	396.75	396.75	0
86	{JAP,GER,FRA,CAN}	379.5	379.5	0
87	{JAP,GER,UK,ITA}	456	456	0
88	{JAP,GER,UK,CAN}	438.75	438.75	0
89	{JAP,GER,ITA,CAN}	385.5	385.5	0
90	{JAP,FRA,UK,ITA}	364.75	364.75	0
91	{JAP,FRA,UK,CAN}	347.5	347.5	0
92	{JAP,FRA,ITA,CAN}	294.25	303.81	9.56
93	{JAP,UK,ITA,CAN}	353.5	353.5	0
94	{GER,FRA,UK,ITA}	344.5	344.5	0
95	{GER,FRA,UK,CAN}	327.25	327.25	0
96	{GER,FRA,ITA,CAN}	274	274	0
97	{GER,UK,ITA,CAN}	333.25	333.25	0
98	{FRA,UK,ITA,CAN}	242	242	0
99	{USA,JAP,GER,FRA,UK}	922,25	922.25	0
100	{USA,JAP,GER,FRA,ITA}	869	869	0
101	{USA,JAP,GER,FRA,CAN}	851.75	851.75	0
102	{USA,JAP,GER,UK,ITA}	928.25	928.25	0
103	{USA,JAP,GER,UK,CAN}	911	911	0
104	{USA,JAP,GER,ITA,CAN}	857.75	857.75	0
105	{USA,JAP,FRA,UK,ITA}	837	837	0
106	{USA,JAP,FRA,UK,CAN}	819.75	819.75	0
107	{USA,JAP,FRA,ITA,CAN}	766.5	766.5	0
108	{USA,JAP,UK,ITA,CAN}	825.75	825.75	0
109	{USA,GER,FRA,UK,ITA}	816.75	816.75	0
110	{USA,GER,FRA,UK,CAN}	799.5	799.5	0

Number	Coalition S	$v(S)$	$v^*(S)$	$v^*(S)-v(S)$
111	{USA,GER,FRA,ITA,CAN}	746.25	746.25	0
112	{USA,GER,UK,ITA,CAN}	805.5	805.5	0
113	{USA,FRA,UK,ITA,CAN}	714.25	714.25	0
114	{JAP,GER,FRA,UK,ITA}	503	503	0
115	{JAP,GER,FRA,UK,CAN}	485.75	485.75	0
116	{JAP,GER,FRA,ITA,CAN}	432.5	432.5	0
117	{JAP,GER,UK,ITA,CAN}	491.75	491.75	0
118	{JAP,FRA,UK,ITA,CAN}	400.5	400.5	0
119	{GER,FRA,UK,ITA,CAN}	380.25	380.25	0
120	{USA,JAP,GER,FRA,UK,ITA}	975.25	975.25	0
121	{USA,JAP,GER,FRA,UK,CAN}	958	958	0
122	{USA,JAP,GER,FRA,ITA,CAN}	904.75	904.75	0
123	{USA,JAP,GER,UK,ITA,CAN}	964	964	0
124	{USA,JAP,FRA,UK,ITA,CAN}	872.75	872.75	0
125	{USA,GER,FRA,UK,ITA,CAN}	852.5	852.5	0
126	{JAP,GER,FRA,UK,ITA,CAN}	538.75	538.75	0
127	{USA,JAP,GER,FRA,UK,ITA,CAN}	1011	1011	0

Appendix 3: Results of $v^*(\{i\})$, $Sh(N, v^* + w)$ for G20

Table A3.1: t ***= 21%***

$t = 0.21$	$v^*(\{i\})$	$Sh(N, v^*)$	$Sh(N, w)$	$Sh(N, v^* + w)$	$Sh(N, v^* + w) - (v^* + w)(\{i\})$
Australia	53.7	41.18	3.69	44.87	-8.83
Canada	50.05	34.31	3.69	38	-12.05
France	50.76	42.25	3.69	45.94	-4.82
Germany	60.83	111.14	3.69	114.83	54
Italy	38.16	44.54	3.69	48.23	10.07
Japan	164.84	139.67	3.69	143.36	-21.48
Korea	44.64	51.95	3.69	55.64	11
Mexico	39	65.42	3.69	69.11	30.11
Turkey	12.78	41.63	3.69	45.32	32.54
UK	72.25	87.82	3.69	91.51	19.26
USA	396.69	397.66	3.69	401.35	4.66
Brazil	54.8	58.09	3.69	61.78	6.98
China	413.8	432.61	3.69	436.3	22.5
India	37.6	75.02	3.69	78.71	41.11
Russia	40.6	59.07	3.69	62.76	22.16
South Africa	19	17.39	3.69	21.08	2.08
Total	1549.5	1699.75	59.04	1758.79	

Table A3.2: *$t = 28\%$*

$t = 0.28$	$v^*(\{i\})$	$Sh(N, v^*)$	$Sh(N, w)$	$Sh(N, v^* + w)$	$Sh(N, v^* + w) - (v^* + w)(\{i\})$
Australia	53.7	53.42	5.81	59.23	5.53
Canada	50.05	43.83	5.81	49.64	-0,41
France	50.76	55.54	5.81	45.94	10.59
Germany	60.83	151.54	5.81	114.83	96.52
Italy	38.16	60.91	5.81	48.23	28.56
Japan	164.84	179.64	5.81	143.36	20.61
Korea	44.64	70.75	5.81	55.64	31.92
Mexico	39	90.5	5.81	69.11	57.31
Turkey	12.78	59.48	5.81	45.32	52.51
UK	72.25	118.85	5.81	91.51	52.41
USA	396.69	523.07	5.81	401.35	132.19
Brazil	54.8	78.22	5.81	61.78	29.23
China	413.8	571.25	5.81	436.3	163.26
India	37.6	103.73	5.81	78.71	71.94
Russia	40.6	81.47	5.81	62.76	46.68
South Africa	19	24.15	5.81	21.08	10.96
Total	1549.5	2266.35	92.96	2359.31	

Appendix 4: Properties of game (N, v^*) and $(N, v^* + w)$

Proposition 1. *The game (N, v^*) is a monotonic game, i.e., for each $S \subseteq T \subseteq N$, it holds that $v^*(S) \leq v^*(T)$.*

Proof. It is enough to prove that $v^*(S) \leq v^*(S \cup \{i\})$ for each $i \in N$ and each $S \subseteq N \backslash \{i\}$. We consider the case where $s > 1$. By definition,

$$v^*(S \cup \{i\}) = \max\left\{\left(\sum_{j \in S \cup \{i\}} \pi_j\right)t; \sum_{j \in S \cup \{i\}} \pi_j t_j\right\} = \max\left\{\left(\sum_{j \in S} \pi_j\right)t + \pi_i t; \sum_{j \in S} \pi_j t_j + \pi_i t_i\right\}.$$

Since $\pi_i t_i > 0$ and $\pi_i t > 0$, we can write that:

$$\max\left\{\left(\sum_{j \in S} \pi_j\right)t + \pi_i t; \sum_{j \in S} \pi_j t_j + \pi_i t_i\right\} \geq \max\left\{\left(\sum_{j \in S} \pi_j\right)t; \sum_{j \in S} \pi_j t_j\right\},$$

which implies that $v^*(S \cup \{i\}) \geq v^*(S)$, as desired. The case where $s = 1$ is similiar and is omitted. ■

Proposition 2. *The game (N, v^*) may not be super-additive., i.e., $v^*(S) + v^*(T) \leq v^*(S \cup T)$ may not hold for all $S, T \subseteq N$ such that $S \cap T = \emptyset$*

Proof. We consider the following numerical example, which we construct from the tax harmonization problem $(N, (\pi_i, t_i, \pi_i^L)_{i\in N}, t, \bar{t})$ such that $\{1,2,3\} \subsetneq N$, $t = 0.3$ and:

i	1	2	3
π_i	60	40	150
t_i	0.25	0.2	0.4

We straightforwardly get that $v^*(\{3\}) = 60$, $v^*(\{1,2\}) = 30$ and $v^*(\{1,2,3\}) = 83$. Hence,

$$v^*(\{1,2\}) + v^*(\{3\}) > v^*(\{1,2,3\}),$$

which shows that the game (N, v^*) is not superradditive. ■

Propositions 1 and 2 highlight other properties of a game $(N, v^* + w)$. Since (N, w) is (trivially) monotonic, $(N, v^* + w)$ is monotonic too (as the sum of two monotonic games). Since $w(S) = 0$, $\forall S \subsetneq N$, $(N, v^* + w)$ may not be superadditive as well.

Proposition 3. *If $t \geq \max_{i\in N} t_i$, then the core of $(N, v^* + w)$ is nonempty.*

Proof. As a start, if $t \geq \max_{i\in N} t_i$, remark that $(v^* + w)$ can be rewritten as follows: for each $S \subseteq N$,

$$(v^* + w)(S) = \begin{cases} \pi_i t_i & \text{if } s = 1, \\ \left(\sum_{i\in S} \pi_i\right)t & \text{if } 2 \leq s \leq n-1, \\ \left(\sum_{i\in N} \pi_i\right)t + \sum_{i\in N} \pi_i^L\big(t - \bar{t}\big) & \text{if } s = n, \end{cases}$$

and keep in mind that $t > \bar{t}$. Next, note that $(N, v^* + w) = (N, r + u)$ where, for each $S \subseteq N$,

$$r(S) = \left(\sum_{i\in S} \pi_i\right)t,$$

and

$$u(S) = \begin{cases} \pi_i\big(t_i - t\big) & \text{if } s = 1, \\ 0 & \text{if } 2 \leq s \leq n-1, \\ \sum_{i\in N} \pi_i^L\big(t - \bar{t}\big) & \text{if } s = n. \end{cases}$$

It is clear that (N, r) is an additive game so that its core contains a single allocation $(\pi_i t)_{i\in N}$. Regarding (N, u), observe that $u(\{i\}) \leq 0$ for each $i \in N$ since $t \geq t_i$ by assumption, that

$u(S) = 0$ if $2 \leq s \leq n-1$ and that $u(N) > 0$ from the fact that $t > \bar{t}$. Hence, any allocation $x \in \mathbb{R}^N$ such that

$$x_i \geq 0 \text{ and } \sum_{i \in N} x_i = u(N) \tag{1}$$

yields that $\sum_{i \in S} x_i \geq 0 \geq u(S)$ for each $S \subsetneq N$. We proved that x is a core allocation in (N, u). Furthermore, it is well-known that the core is covariant under strategic equivalence (see Peleg and Sudhölter, 2003, for instance), which implies that the core of $(N, r+u)$ is composed of the allocations of the form $z + (\pi_i t)_{i \in N}$, $z \in C(N, r)$. Therefore, we obtain that the core of $(N, r+u)$ contains the allocations y such that that, for each $i \in N$, $y_i = x_i + \pi_i t$, where x is described by (1). From $v^* + w = r + u$, conclude that the core of $(N, v^* + w)$ is nonempty, although the Shapley value may not be a core allocation. ■