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Abstract

An allocation rule is "non-bossy" if whenever a change in an agent's preferences does not bring about a change in his assignment, then it does not bring about a change in anybody's assignment. We discuss the multiple interpretations that have been proposed for this property. We question their validity, arguing that in most cases, non-bossiness either says too little or that is says too much. We also make a case against the property. We propose as its main justification the technical help that it often provides in structuring classes of rules, making characterizations more manageable.

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1 Introduction.

A property of allocation rules that has played an important role in the development of the axiomatics of resource allocation is the so-called "non-bossiness" property (Satterthwaite and Sonnenschein, 1981). It says that whenever a change in an agent's preferences does not cause a change in his assignment, it should not cause a change in anybody else's assignment: thus, the entire allocation should remain the same. The purpose of this paper is to assess its significance. What is *non-bossiness* really about? When are we justified in imposing this requirement? Are we ever justified in doing so?

Its significance is rarely discussed, and when they introduce the property, most authors seem to take its desirability as self-evident. Its name suggests that it contributes to preventing the distribution of influence in the allocation process from being too skewed. Nobody likes to be bossed around and requiring *non-bossiness* should be uncontroversial. A strategic interpretation has been noted as well, and the property is almost always invoked in conjunction with the requirement, called "strategy-proofness", of immunity to misrepresentation of preferences by individuals. Satterthwaite and Sonnenschein themselves motivate *non-bossiness* on the basis of considerations of informational simplicity. They also point out that, in the context of standard private good economies, it disqualifies any rule that assigns all the resources to one or the other of two agents, chosen in advance, depending upon some arbitrary feature of the preferences of some third agent, also chosen in advance. Referring to these examples, Barberà and Jackson (1995) argue in favor of the property by saying that "it rules out a series of social choice functions which are not dictatorial but are degenerate in other ways". They do not spell out these "other ways", but we see two features of the Satterthwaite-Sonnenschein "bossy" rules that make them unappealing. First is their discontinuous behavior; the violations of continuity are quite radical since they affect the entire endowment. Second, they produce highly "unbalanced" allocations; they always assign all of the resources to a single agent.

On the other hand, *non-bossiness* is sometimes presented as a technical requirement of the kind to which researchers sometimes resort in order to attain a characterization that would elude them otherwise, but that has no strong interest of its own. It is then occasionally invoked with a mild apology. The fact that no one has ever taken as a primary objective to characterize the class of *non-bossy* rules for any model indicates the profession's perception that it is not worthy of independent study. Further evidence of it is that some authors have explicitly expressed discomfort in imposing *non-bossiness*, and that others have stated that the fact that a characterization they established did not involve the property added to the significance of their contribution.[1]

Our goal is to review and assess these conflicting views. We begin with a formal statement of the property and of the variants that have been proposed, using language that is as neutral as possible so as not to unwittingly invest it with meanings that would obscure what the property is really about, as has unfortunately often been the case. Adding to the confusion caused by the various, partially contradictory or ambiguous justifications for *non-bossiness* listed above is indeed the fact that standard "dictatorial" or "sequential dictatorial" rules are *non-bossy*. Our conclusion here is that most common interpretations either do not apply as claimed, or are unsupported.

We first dispose of two possible interpretations of the property as having to do with what in common language we refer to as "bossiness".

Next, we point out various connections between *non-bossiness* and other properties that do have clear strategic or normative content, but we claim that there is "too little" of these properties in *non-bossiness* for these connections to constitute very solid grounds on which to argue in its favor. In some characterizations, one of these stronger properties is met (sometimes several of them are) by the rule whose uniqueness is established, and a characterization in which the property is explicitly invoked would yield a more compelling, if perhaps logically weaker, result. Then, *non-bossiness* is "too little".

When the stronger property is incompatible with some others, but we obtain a characterization of a rule (or a family of rules) based on these other properties and *non-bossiness* together, the question should be raised of what exactly we have gained by including *non-bossiness*. In these cases, it feels like "too much" because it does not strengthen in any significant way the attractiveness of the rule that is characterized (or the rules that are characterized), yet at the same time, it may exclude rules that enjoy properties that do have straightforward interpretation and clear appeal. *Non-bossiness* is certainly "too much" when, in conjunction with other axioms that we impose, an incompatibility emerges, but the other axioms are compatible. In

[1] Serizawa (1999) writes: "It has also been an important research question whether or not we can substitute for nonbossiness a simple, weak, and economically meaningful condition."

some contexts, it paradoxically disqualifies rules that satisfy properties on the basis of which *non-bossiness* is unjustifiably advocated.

Finally, some fairness underpinnings have been proposed for *non-bossiness* that seem besides the point. Indeed, their formal expressions are properties that are satisfied by rules that violate *non-bossiness*, and conversely *non-bossy* rules exist that violate the properties. This is also the case for the argument of informational simplicity mentioned earlier: rules exist that qualify in that respect but violate *non-bossiness*, whereas *non-bossy* rules exist that do not qualify. The same comment applies to *continuity*.

So, should we ever want to impose *non-bossiness*? We see two reasons why we could. First, because it is implied by a wide range of different properties, a violation of *non-bossiness* is quite informative. Also, *non-bossiness* often does help in structuring a class of rules, and thereby in leading to characterizations that can be a useful starting point. This seems to be the main argument in favor of the property. It is not an insignificant one, but we would be better served by acknowledging this technical assistance that *non-bossiness* sometimes provides instead of bringing up arguments of dubious value in its favor.

Because our purpose is mainly to evaluate concepts, we have avoided technical definitions as much as possible. In the appendix, we derive simple proofs of some assertions stated in the main text. We introduce the necessary formalism at that point. Tables 1-2, which appear in the conclusion section, summarize the various logical relations between *non-bossiness* and other properties discussed in the main text.

2 Formal statement, variants, and examples

Let $\mathcal{R}$ be a domain of preferences. A **rule** is a mapping φ defined on $\mathcal{R}^N$, the cross-product of $|N|$ copies of $\mathcal{R}$ which takes its values in some allocation space X^N. Given $i \in N$, let $\varphi_i(R)$ designate agent i's assignment at R.

The property of a rule under scrutiny here is the following: if, when the preferences of some agent change, his assignment is unchanged, then nobody else's assignment should change: the entire allocation should remain the same.

Non-bossiness: (Satterthwaite and Sonnenschein, 1981) For each $R \in \mathcal{R}^N$, each $i \in N$, and each $R'_i \in \mathcal{R}$, if $\varphi_i(R) = \varphi_i(R'_i, R_{-i})$, then $\varphi(R) = \varphi(R'_i, R_{-i})$.

The following family of rules, informally described in the introduction, is a standard illustration of a violation of *non-bossiness*. In a **classical fair division problem**, a social endowment of infinitely divisible goods has to be distributed among a group of agents. Agents are equipped with continuous preferences satisfying some monotonicity and convexity properties. (Various forms of these properties have been considered, but for our purposes here, there is no need to go into details.)

A **Satterthwaite-Sonnenschein rule** (1981) is defined as follows. For simplicity, we consider the three-agent case, setting $N \equiv \{1, 2, 3\}$. Partition the set of possible preferences for agent 1 into two non-empty subsets, $\mathcal{R}^2$ and $\mathcal{R}^3$. If agent 1's preferences belong to $\mathcal{R}^2$, assign the entire social endowment to agent 2; otherwise, assign it to agent 3.

Satterthwaite and Sonnenschein introduced these rules in a study of **strategy-proofness**, the requirement on a rule that for each preference profile, in the direct revelation game associated with the rule, for each agent, telling the truth should be a dominant strategy. For their rules, there is one bossy agent, and he never gets anything. So, being bossy does not necessarily bring material advantages. As already mentioned, in spite of the name they chose for it, Satterthwaite and Sonnenschein advocated *non-bossiness* as a property of informational simplicity of rules. (We discuss their position in Section 6.)

Depending upon whether *non-bossiness* is viewed from a normative or strategic perspective, we will have to think of the two preferences that are mentioned in its hypotheses as (i) an agent's true preference relation and a lie, or (ii) two possible preference relations that he may truly have.[2]

Variants of *non-bossiness* can be formulated in which either the hypothesis or the conclusion is written, or both are, in welfare terms. We will occasionally mention these variants because, as we will see, some of the interpretations of *non-bossiness* that some authors have proposed suggest that it is one of them that they should have imposed, not *non-bossiness* itself.

1. **Non-bossiness in welfare on the conclusion side** says that if a change in an agent's preferences is not accompanied by a change in his assignment, then the welfare of none of the other agents should be affected. It is a weaker property than *non-bossiness*.

[2]The index i is generally understood to refer to a specific agent but if (i) is adopted, it may more generally refer to a "position" in an economy. The position may be filled by agents with one of several preferences.

2. The hypothesis may be that the welfare of the agent whose preferences change remains the same according to one of the two relations that are contemplated for him (the relations play symmetric roles, so it does not matter which it is). Then, we have **non-bossiness in welfare on the hypothesis side**. We obtain a weaker version by writing as hypothesis that the welfare of that agent remains the same according to both of the relations that are contemplated for him. Let us call it **weak non-bossiness in welfare on the hypothesis side**.[3] When the total resources to be assigned are fixed, which is the case for most models in which the property has been studied, the possibility of having an agent's assignment move along one of his indifference curves is hardly ever compatible with keeping the same assignments for the other agents. If the physical assignment to the agent whose preferences change is affected by the change, and whether or not some statement can be made about a possible change in his welfare, the resources assigned in total to the other agents will change, which will make it impossible to assign to each of them the same bundle as initially. If we do not require that the resource constraint be met as an equality, there will be some room for adjustments however. For the same reason, in the two-agent case, *non-bossiness* itself is vacuously met unless resources can be disposed of. This is why the property has always been invoked (as far as we know) for three agents or more.

3. Next are variants obtained by expressing both hypotheses and conclusions in welfare terms. There are two versions as well, depending upon whether we write the welfare statement on the hypothesis side for one of the two relations appearing there, or for both. Let us refer to them as **non-bossiness in welfare on both sides** (when the hypothesis is a welfare statement for only one of the relations), and **weak non-bossiness in welfare on both sides**, when we write the welfare statement for both relations.

We close with properties that are further away from our primary definition.

4. **SSY non-bossiness** (Saijo, Sjöström and Yamato, 2007)[4] says the

[3] Berga and Moreno (2009) refer to the former as "non-bossiness", and to the latter, introduced by Ritz (1983), as "weak non-bossiness". Ritz has in mind a strategic interpretation for the property and calls it "non-corruptibility". Olson (1991) also uses the expression "non-corruptible". We prefer avoiding it because of the other, non-strategic, interpretations that can be given to the property.

[4] These authors refer to it as "weak non-bossiness", and Berga and Moreno (2009) as "quasi-non-bossiness".

following: for each agent and each profile of preferences for the other agents, if a change in his preferences results in two different choices, then there should be alternative preferences for them such that the same change in his preferences affects his welfare at the two resulting choices according to both of the relations.

5. Next is a version of *non-bossiness* in which the agent whose preferences change is required to belong to a pre-specified group, his preference changes are limited in that his strict lower contour set and his strict upper contour set at the chosen alternative remain the same, and the invariance-of-assignment conclusion is limited to the other members of this pre-specified group (Barberà, Berga, and Moreno, 2014).[5] Thus, it is a three-fold weakening of *non-bossiness*.

6. A model-specific restricted version of *non-bossiness* for the problem of fully allocating a social endowment of a single commodity when preferences are single-peaked is defined by Sakai and Wakayama (2012). They add to the hypotheses that the peak amount of the agent whose preferences change remains the same.

7. Another version pertains to models in which each agent's consumption space is a product of the real line and some other space. Preferences are strictly monotone with respect to the first good, which we call "money" for convenience, and can be represented by a function that is separably additive with respect to (i) money, and (ii) a second argument, a point in that second space, which represents consumptions of the non monetary goods. The property says that when a change in an agent's preferences is not accompanied by a change in his assignment of the non monetary goods, then nobody else's assignment of these goods should change. Let us refer to it as **subspace non-bossiness**. It is introduced[6] by Nath and Sen (2014) and it appears in Mukherjee (2014) and Mishra and Quadir (2014). There is no obvious logical relation between *non-bossiness* and *subspace non-bossiness* since both the hypothesis and the conclusion of the former are stronger than those of the latter. In fact, there are rules satisfying *subspace non-bossiness* but not *non-bossiness* (Section 8).

[5]These authors refer to it as "H-respectfulness", H designating the pre-specified group.

[6]Under the name of "allocation non-bossiness".

3 Bossiness in common language

First, we ask whether *non-bossiness* has anything to do with what we mean by the term "bossiness" in common language. The question needs to be asked since the property could be advocated on the basis of the general dislike that most people have of bossy behavior. We will argue that the answer is a clear no.

As usually understood, "bossiness" is a character trait. A bossy person is one who is "given to ordering people about, overly authoritative, domineering, and dictatorial". Such a person unjustifiably intervenes in other people's affairs, telling them what to do. Stretching the definition a little, giving unwanted advice may be part of the behavior. Therefore, the term "bossy" certainly cannot be applied to a rule, except perhaps as shorthand to mean that it "allows bossiness". In the context of resource allocation, why would a person behave in a bossy way? We propose two possible answers.

1. One is that his welfare is affected by what the other agents consume: his preferences exhibit *external effects*. In a model in which agents' preferences over their own assignment is the only information on which the definition of a rule is based—and to the best of our knowledge, *non-bossiness* has only been invoked in such contexts—this interpretation cannot be sustained. If the change in an agent's announcement does not affect what he is assigned, the model specifies that any possible impact on the other agents' assignments should not affect his own welfare. Situations in which there may be externalities in consumption are not the context in which *non-bossiness* has been formulated and studied.

Let us see what *non-bossiness* would mean in such a situation. Externalities can be modeled in different ways. In addition to his own assignment, an agent may care about the other agents' assignments, or he may simply care about their welfare. This dependence may be positive or negative (he may be spiteful).

The minimal departure from the standard self-regarding specification of preferences is perhaps a lexicographic formulation: an agent gives precedence to his own assignment, and ranks two allocations in terms of a relation that only depends on what he gets; if that relation places his assignments at these two allocations on the same level, he refines his ranking by turning to the other agents' assignments or welfare.

If it is about the other agents' welfare that he cares and not about their physical assignments, it would be most natural to impose *non-bossiness in* *welfare on the conclusion side*, not *non-bossiness* itself.

2. The other departure from the standard specification of preferences that might make *non-bossiness* meaningful, as this term is commonly understood, is when an agent's welfare is affected by the *process* through which allocations are chosen. For instance, an agent may derive satisfaction from having control over it. Here too, in none of the studies in which *non-bossiness* has been invoked, have preferences been defined over allocation processes. So, this interpretation is just as problematic.

The idea that preferences may depend on the allocation process itself has been discussed in the context of implementation theory. Some authors have objected to game forms in which not all players play symmetric roles even though they might be treated symmetrically by the correspondence that is to be implemented. In fact, the correspondence may be chosen for its fairness properties. An example is the **no-envy** solution (Foley, 1967), which selects for each economy, the allocations such that no agent prefers someone else's assignment to his own. In such game forms, out of equilibrium, an agent may be able to exercise more control over the other agents' assignments than some other agents (it is the case in the game forms proposed by Thomson, 1995, and Doğan, 2012, to implement the no-envy solution). In the general game forms of the type proposed by Maskin (1999), the strategy spaces of the various agents are indeed not necessarily the same even when the correspondence to be implemented exhibits no asymmetries. There is then an intuitive sense in which some agents have more control over the allocation process than others. We say "intuitive" because of a lack of a canonical way of formally organizing allocation processes according to how much control they give to each agent over what he or his fellow agents receive. Any formulation is likely to be ad hoc and to produce very partial orders; we will not attempt to offer one. In any case, at equilibrium, this opportunity to be bossy is not necessarily to an agent's advantage, as is made clear by the Satterthwaite-Sonnenschein rules.

Summarizing, either one of our attempts to justify *non-bossiness* as understood in common language seems to require specifications of preferences that are too far removed from their actual specifications in the models in which the property has been imposed for this justification to be sustainable.

4 Non-bossiness as a strategic property

We evaluate here the interpretation of *non-bossiness* from a strategic perspective, as a property that helps ensure that agents report their preferences truthfully. We argue that for this interpretation to be justified, the property should be strengthened or complemented by other properties of robustness to strategic moves that agents may make. *Non-bossiness* is not enough then.

Why should we care if a rule is not fed the proper information? It is simply that the wrong allocation decision is likely to be made. We choose a rule because of the properties it enjoys, such as its efficiency and distributional properties, or because of incentives it provides agents to exert themselves. These objectives may not be achieved if it is manipulable. Of course, if it is manipulable, it may well be manipulable by more than one agent, and to really understand the consequences of the behavior, we should engage in its full-fledged game-theoretic analysis. For each preference profile, we should identify the equilibria of the manipulation game associated with it, and we should compare the resulting allocations (there may be more than one) to the allocation that would have been selected in the absence of manipulation (Hurwicz, 1972).

4.1 Preventing certain types of collusion

Non-bossiness has often been advocated as the expression of the robustness of a rule to certain types of collusion. If, by changing his announcement, an agent affects some other agent's assignment, (or several agents' assignments, but for our discussion, it will suffice to assume that he affects only one agent's assignment,) we may have to worry about him doing so even if his own assignment is unchanged: if this second agent benefits from the change, he will have an incentive to approach the first agent and suggest to him that he, the first agent, engage in the manipulation. After the rule is applied, we will say **post-application**, some transfer may be needed to ensure that the first agent gets something out of his misrepresentation and follows through. We can of course also think of the first agent taking the initiative and suggesting a deal to the second agent.

The property has been discussed in situations in which transfers are not explicitly modeled, such as the variety of object-allocation or object-reallocation problems that have been much studied recently (more on those later), but any allocation problem takes place in a broader context than that formally described in the models that we write down. In that broader context, compensation is often possible. Note that if the second agent's assignment is affected but his welfare is not, the incentives we just talked about do not exist, so this interpretation suggests that it is *non-bossiness in welfare on the conclusion side* that we should impose. Let us comment on this strategic interpretation of *non-bossiness*.

1. **Non-bossiness without strategy-proofness?** First, if is is adopted, it does not make much sense to think of *non-bossiness* independently of *strategy-proofness*. (As we noted in the introduction, *non-bossiness* has indeed rarely been imposed separately from *strategy-proofness*.) This is because any agent who expects to gain through a misrepresentation of his preferences that leaves his assignment unchanged but impacts someone else's assignment is bound to ask himself whether some misrepresentation would be available that benefits him directly. It is presumably for that reason that some authors have judged that the two properties should be combined into one.[7]

A further reason for thinking of *strategy-proofness* as a necessary complement to *non-bossiness* is that for a *strategy-proof* rule, the sort of manipulation that *non-bossiness* is intended to prevent is particularly safe. Announcing the truth is a dominant strategy for the direct beneficiary of the manipulation, so for him, there is no risk. Since the agent who misrepresents is assigned the same thing whether he tells the truth or announces the lie that appears in the hypotheses of the property, there is no risk for him either.

2. **Non-bossiness without pairwise strategy-proofness?** One should not stop at *strategy-proofness* though. If the possibility of collusion described above is taken as the reason for imposing *non-bossiness*, why shouldn't two agents whose collusion we are concerned about not take a further step and think about joint misrepresentations of their preferences? Why shouldn't they take advantage of these two instruments at their disposal to affect the allocation in their favor? It may even be the case that both are made better off by some joint misrepresentation, without their having to resort to post-application transfers. Then, the appropriate requirement to impose on a rule is **pairwise strategy-proofness**: for each preference profile, there should be no pair of agents who can jointly misrepresent their preferences in such a way that each of them ends up at least as well off as if they had not done so,

[7]Olson (1991) and Miyagawa (1997) have proposed that the two properties be merged. The first author refers to a rule satisfying this conjunction as "non-strategic" and the second as "strongly strategy-proof".

and at least one of them ends up better off.

Thus, to the question "Can non-bossiness be imposed independently of *pairwise strategy-proofness*?" we would answer: probably not. As for the questions we ask next, our answers will be more nuanced. They will depend on whether we feel that the case for *non-bossiness* requires a transfer to the agent who is supposed to misrepresent his preferences to induce him to actually do so. By contrast to preference misrepresentation, which can never be established for sure, transfers of physical resources can in principle be monitored, and if they are forbidden, a penalty may be levied upon detection.

3. **Non-bossiness without bribeproofness?** If transfers are within the realm of what a manipulating pair is willing to consider, and returning to the scenario when only one agent in the pair misrepresents, why shouldn't they also consider misrepresentations that initially affect him negatively if after receiving a compensation from the other, he ends up better off? It seems natural then not to stop at *pairwise strategy-proofness*, that we should require of a rule that it be immune to manipulations of this type.

This is what the property considered next is meant to prevent. The scenario is the one we just described: one agent misrepresents his preferences, and some other agent's assignment is affected in such a way that, after some appropriate transfer to the first agent, both are better off. **Bribe-proofness** says that such beneficial arrangements should not be possible (Schummer, 2000). Before the transfer, the agent who misrepresents may be worse off than if he had not misrepresented, a possibility that is of course excluded by the hypotheses of *non-bossiness*. Thus, it does mean that the misrepresentation is more risky for him. It requires that he trusts that post-application, his co-conspirator indeed follows through and makes the transfer that they had planned. This may be problematic when the transfer needed to bring him up to his no-manipulation welfare is large. (Admittedly, this qualification involves a cardinal notion, whereas our analysis so far has been cast in purely ordinal terms.)

4. **Non-bossiness without pairwise efficiency?** This scenario involving transfers just described suggests that the rule on which *bribe-proofness* is imposed should be, if not *efficient*, at least *pairwise efficient*. In some contexts, such as allocation in classical economies when preferences are smooth, *pairwise efficiency* implies *efficiency*, but there are contexts where the implication fails. (Examples are classical economies when preferences are not necessarily smooth, and most models of allocation or reallocation of discrete

resources). Otherwise, two agents who could perform a transfer between themselves that improves their post-application welfare would do so, thereby getting in the way of the planner's objectives without having to engage in any misrepresentation. Of course, we should ask why a planner's objective would not include *pairwise efficiency*, but this property, like all others, is occasionally incompatible with combinations of other desirable properties, and the planner may have chosen to give priority to these properties.

Summarizing, seen as a property of strategic robustness, *non-bossiness* makes sense only when imposed on rules that are *strategy-proof*, in fact *pairwise strategy-proof*. Moreover, if we think that a post-application transfer is required to ensure that the agent who is supposed to misrepresent does so, we should assume the rule to be *pairwise efficient*. Altogether, the rule should be *pairwise efficient* and *immune to pairwise misrepresentation and post-application transfers*.

Finally, if transfers are within the realm of what agents are willing and safely able to carry out, in situations in which each agent has control over a private endowment, we should perhaps add the requirement that the rule be immune to what we could call **pre-application** transfers as well. If agents can engage in both pre-application and post-application transfers, the robustness property we demand should be *immunity to pairwise misrepresentation and pre- and post-application transfers*.

5. **Non-bossiness without group strategy-proofness?** If we believe that *non-bossiness* should be accompanied by some requirement of immunity to misrepresentation by groups, there are good reasons to focus on two-agent groups as the relevant strategic entities, as we have done so far. Indeed, the larger a group, the less likely it is that its members will be able to identify successful joint misrepresentations, agree on one that would benefit all of them in a way they judge fair, and carry it out without fear of double-crossing. Thus, requiring robustness of a rule to strategizing by groups of all sizes is in most situations probably more robustness than is needed. In other words, we do not feel that **group strategy-proofness** should necessarily be required: this is the strengthening of *pairwise strategy-proofness* that calls for immunity to joint misrepresentation by groups of arbitrary sizes: for each preference profile, there should be no group of agents who can jointly misrepresent their preferences in such a way that each of its members ends up at least as well off, and at least one of them ends up better off. The possibility that a manipulating group will carry out post application transfers among

themselves may also be too remote, given the coordination that this would require. What is a reasonable size? Obviously, that will depend on the situation, but imposing robustness to strategizing by two agents is the first step beyond imposing robustness to strategizing by isolated agents. Wanting to understand whether this first step significantly constrains rules is quite natural.

However, it turns out that in a number of contexts, *non-bossiness* and *strategy-proofness* actually lead to *group strategy-proofness* itself. An example is for the allocation of a social endowment of infinitely divisible goods among agents equipped with preferences satisfying the "classical" assumptions of continuity, monotonicity, and convexity (Barberà and Jackson, 1995).[8] A list of other models for which this is the case is given in Appendix A. The appendix also contains a list of models for which the implication fails. What sometimes appear to only be small variations in a model may suffice to cause the implication to fail where initially it held. Neither list is exhaustive, but together they may help establish a theorem that is missing from the literature, namely one identifying conditions on domains for the implication to hold.

Weak group strategy-proofness says that for each preference profile, there should be no group of agents who can jointly misrepresent their preferences in such a way that each of its members ends up better off. Although it follows directly from the definitions that *group strategy-proofness* implies *non-bossiness*, it is not the case that *weak group strategy-proofness* does (Sönmez and Switzer, 2013).

In situations in which *non-bossiness* and *strategy-proofness* together imply *group strategy-proofness*, and given the difficulties encountered with interpreting *non-bossiness* from a strategic viewpoint, cleaner results would be obtained by directly imposing *group strategy-proofness*. On the other hand, when the implication fails, imposing *non-bossiness* may restrict rules without adding anything of significance to their strategic robustness.

4.2 Maskin invariance and Nash implementation

What we just discussed is the relevance of *non-bossiness* to preventing coordinated strategizing by agents, but the property also has a connection to a

[8] To the best of our knowledge, this is the first paper in which an implication of this type has been established.

property of rules that is critical for their implementation in Nash equilibria, their **Nash implementability**, when each agent chooses his strategy independently of the others. This property, which is necessary and in many contexts, sufficient, for *Nash implementability*, is **Maskin invariance** (Maskin, 1999)[9]: if an alternative is chosen for some preference profile and preferences change in such a way that the new lower contour set of each agent at that alternative contains his initial lower contour set at the alternative, then it should be chosen for the new profile.

Under certain richness assumptions on the domain of admissible preferences, *Maskin invariance* implies *non-bossiness* (Shenker, 1992; Mizukami and Wakayama, 2009). Thus, *non-bossiness* derives some interest from its connection to *Maskin invariance*, but we are not aware of a weaker notion of implementability that a rule that is *non-bossy* but not *Maskin invariant* satisfies. Thus, this connection does not help much in achieving other, perhaps weaker, implementation objectives.

5 Non-bossiness as a normative property: four interpretations

In this section, we uncover connections between *non-bossiness* and normatively appealing properties and discuss the significance of these connections. What underlies the properties are relational considerations of solidarity and punctual considerations of fairness, and *non-bossiness* inherits these interpretations. However, we will also argue that here too, it does not contain "enough" of these properties to benefit much from the connection.

5.1 Welfare-dominance under preference replacement.

The general idea of solidarity is that if the circumstances in which a group of agents find themselves change, and if nobody in the group has any particular responsibility for the change (deserves any credit for it if it is favorable, or blame if it is not), then the welfares of all of these agents should be affected in the same direction. It may be the resources available for distribution that change, or the technology, or the population, or the characteristics of some agents, such as the resources they own or control, or their preferences. We

[9]The property is usually called "Maskin monotonicity".

are interested here in the expression of solidarity in response to changes in the preferences of some agents: it says that the welfare of all other agents should be affected in the same direction. Let us refer to the requirement as **welfare-dominance under preference replacement**.[10]

Consider a domain of economies with monotonic preferences and an *efficient* rule. Apply it to some economy in its domain, and imagine that the preferences of some agent change. If there is no production, and the agent whose preferences change is still assigned the same thing, the resources available to the others are still the same as well, and because the rule is *efficient*, the requirement that the welfares of all of these agents should be affected in the same direction—we could call this requirement **1-agent welfare-dominance under preference replacement** to distinguish it from the more general statement introduced earlier—implies that each of them should be indifferent between his old and new assignments. We end up with *non-bossiness in welfare on the conclusion side*. In a number of situations of interest, no two allocations are Pareto-indifferent, so this is possible only if in fact, each of them is assigned the same thing. Then, we obtain *non-bossiness* itself. Examples of such situations are the following:

(a) Allocating a social endowment, or reallocating private endowments, of infinitely divisible goods among a group of agents equipped with preferences that are continuous, monotone, and strictly convex.

(b) Allocating a social endowment of objects, or reallocating private endowments of objects, among a group of agents equipped with strict preferences.

(c) One-to-one or several-to-one two-sided matching when preferences are strict.

If the "strictness" assumption in each of (a), (b), and (c) is not made, there may be several allocations at which the welfare of each of the agents whose preferences remain fixed is maintained. Suppose that we allow allocation mappings to be multi-valued, and that we impose **Pareto indifference** on them, the property that for each allocation a mapping chooses, it should choose each allocation that is Pareto-indifferent to it. Then again, the welfare dominance property will imply that if the preferences of an agent change but his assignment is unaffected, the welfare of each of the other agents should

[10]The property is introduced by Moulin (1987) in the context of binary social choice under the name of "agreement". It has been studied in a wide variety of models. For a survey, see Thomson (1999).

be unaffected. This is *non-bossiness in welfare on the conclusion side*, as we announced.

Non-bossiness is a relational property, and it does not say anything about whether the allocations chosen by a rule satisfy any punctual requirement of fairness. The choices the rule makes may be skewed in favor of particular agents, and in fact they may be *systematically* skewed in favor of particular agents—**dictatorial rules** and **sequential priority rules**[11] themselves are typically *non-bossy*. However, *non-bossiness* implies that whatever distributional choices a rule makes, it makes them in a "consistent" way, giving to the term the meaning it has in common language (as opposed to the technical meaning that is discussed in the next subsection).[12]

Thus, *non-bossiness* can be seen as a weak, "conditional", form of *welfare-dominance under preference replacement*. Our position here is that, if this connection is taken as a reason to impose the property, it is hard to see why the scope of the solidarity requirement should be limited to changes in the preferences of only one agent, and to situations in which that agent's assignment is not affected by the change.[13]

[11]For a dictatorial rule, there is an agent, chosen ahead of time and once and for all, whose welfare the rule always maximizes. The same set of alternatives may all be most preferred for several of his possible preferences, and among them, the rule may select in a manner that leaves his assignment unchanged but makes the other agents' assignments depend on what his preferences are. Given an order on the agent set, the sequential priority rule associated with that order selects the alternative that is most preferred by the agent who is first if there is a unique such alternative; if not, among the alternatives that are most preferred by this agent, it selects the one that is most preferred by the agent who is second, if there is a unique such alternative, and so on. *Non-bossiness* holds because the order is specified once and for all, before preferences are known.

[12]We say "typically" because a "conditional" type of sequential priority rule can be defined for which at each step, the identity of the agent who is next is made to depend on the preferences of the agents who have chosen so far. Such rules are obviously bossy.

[13]Adachi and Kongo (2013) propose a version of *non-bossiness in welfare on both sides*, under the name of "strong non-bossiness in welfare", which has an even closer connection to *welfare-dominance under preference-replacement*. On the hypothesis side, indifference is required only for one of the relations that are contemplated for the agent whose preferences change, and the requirement is that all other agents should find their assignments when he makes that particular announcement at least as desirable as when he makes the second announcement. It is a form of *welfare-dominance under preference replacement*. The two preference relations that are contemplated for agent i do not play the same role, so the conclusion is not that the welfare of all of the other agents should remain the same. The hypotheses is weaker than the hypotheses of *welfare-dominance*.

5.2 Consistency.

We consider next the possibility that the population of agents may vary and the following property of a rule. Having applied it to an economy in its domain, we imagine that some agents leave the scene with their assignments, and we reevaluate the situation at that point, that is, we consider the "reduced economy" in which whatever remains of the resources available initially has to be allocated among the remaining agents. The rule is **consistent** if in this economy, it chooses the same assignment for each of these agents as it did initially.[14]

It is well-known that if a rule is *consistent*, it is *non-bossy*. In fact, the weaker version of *consistency* obtained by imagining the departure of one agent with his assignment—let us call it **1-person consistency**—implies *non-bossiness*. In most models, there is indeed no difference between *consistency* and its 1-person version.[15] Several interpretations have been given of *consistency*, and because of this logical relation, these interpretations may provide additional arguments in favor of *non-bossiness*. They are reviewed in Thomson (2012, 2014a), who challenges the case that has been made for *consistency* on the basis of punctual fairness considerations (Balinski and Young, 1983):[16] to the extent that *consistency* has to do with distributional objectives, it is not with punctual fairness, but rather with the relational notion of solidarity.

In any case, this logical relation between *non-bossiness* and *consistency* does not bring additional arguments in favor of *non-bossiness* as directly as its logical relation to *welfare dominance under preference replacement*. Indeed, although *non-bossiness* can be seen as a conditional form of *welfare dominance*, as explained above, *non-bossiness* is a fixed-population property,

[14]The consistency "principle" has been the object of a large literature, reviewed in Thomson (2014a). The axiom of *consistency* can also be written for solution correspondences, but since here, we focus on its connection to *non-bossiness*, a property of rules, we have stated it for rules.

[15]This is the case whenever the reduction operation is "transitive". This means that reducing an economy with agent set N with respect to some subgroup N' of N and some outcome x, and then reducing the resulting economy with respect to some subgroup N'' of N' and $x_{N'}$ is the same thing as directly reducing it with respect to N'' and x. Transitivity holds for the models discussed in these pages.

[16]They restate *consistency* as the requirement that "Every part of a fair allocation should be fair". We argue in Thomson (2012) that this description is not supported by the formal definition.

which *consistency* is not. Thus, *non-bossiness* never relates the choices a rule makes across economies of different sizes. It is not "*consistency* applied to a subdomain".[17]

Another problem with advocating *non-bossiness* on the grounds that *consistency* implies *non-bossiness* and *consistency*'s own merits, is that this relation implicates an application of *consistency* under very restricted circumstances: the proviso that the assignment to the agent whose preferences change should remain the same makes its scope very narrow. We raised a similar point above in connection with *welfare dominance*. Also, as for *welfare dominance*, it is hard to justify allowing changes in the preferences of only one agent. If this restriction is dropped, a property with a clearer normative meaning would certainly result. This property is discussed in Section 7.

5.3 Fair distribution of resources

We mentioned in the introduction two features of the Satterthwaite-Sonnenschein rules that make them unappealing. The first one, discussed in this subsection, is that they yield very uneven distributions of resources. Although they are not dictatorial, in each economy, the entire social endowment is assigned to a single agent. Besides, only two agents are possible recipients of it.

Of course, other bossy rules could be constructed for which violations of fairness would not be as radical (for example, we could make it so that $n-1$ agents are possible recipients of the social endowment depending upon some arbitrary feature of the remaining agent's preferences). Assigning the entire endowment to a single agent is a convenient way to guarantee *efficiency*, but we could obtain this property with less dramatically uneven distributions of resources. For instance, depending upon some arbitrary feature of agent 1's preferences, we could apply the Walrasian rule from an equal division of the social endowment among $N \setminus \{2\}$ or among $N \setminus \{3\}$. (*Strategy-proofness* would certainly be violated then.)

However, if fairness is our concern, instead of formulating a property tailored to prevent the peculiar occurrences of unfairness exhibited by the Satterthwaite-Sonnenschein rules, a more sensible approach it to bring into

[17] Of course, *non-bossiness* does not imply *consistency*. To see this consider, in our variable-population framework, a sequential priority rule in which the orders in which assignments are calculated are chosen independently population by population. Such a rule is not *consistency* unless the orders with which its components are associated are induced from a single reference order on the entire population of potential agents.)

the picture formal notions of fairness in distribution. An array of such notions have been proposed in the literature. Minimal punctual requirements are that (i) no agent should *always* be assigned the entire social endowment or (i') that no agent should *ever* be assigned the entire social endowment; (ii) that no agent should *always* be assigned nothing or (ii') that no agent should *ever* be assigned nothing. Most people would argue that such properties are far from being enough. We list the next six notions, which are more demanding, in pairs; one notion pertains to situations in which resources are held collectively; the other pertains to situations in which each agent has his own endowment. They are (iii) Pareto-domination of equal division or (iii') Pareto-domination of the endowment profile; (iv) no-envy or (iv') no-envy in trades; (v) egalitarian-equivalence or (v') egalitarian-equivalence in trades. We could add to this list (vi) various notions of equal opportunities (Thomson, 2011, is a survey). Thus, someone who cares about fairness in distribution has an ample inventory of concepts to draw upon as formal expressions of his concern.

Besides, as we already noted, standard dictatorial rules are *non-bossy*, and since such rules violate all of the notions of punctual fairness in distribution just enumerated, the issue of *non-bossiness* is in fact orthogonal to the issue of punctual fairness. If the latter matters to us, resorting to *non-bossiness* seems misdirected.

5.4 Continuity

Another unappealing feature of the Satterthwaite-Sonnenschein rules is that small changes in preferences may cause major changes in outcomes. **Continuity** with respect to preferences as well as other parameters is a desirable property for several reasons. The exact amounts of the various goods to be allocated, the exact technology that is operated, the exact preferences of their recipients, and so on, are accidental features of the situation they face. Intuitively, we feel that small variations in this data should not have the radical impact on welfare that the Satterthwaite-Sonnenschein rules exhibit. We can well imagine that participants would object to small changes in the data defining an economy, errors in specifying preferences or corrections of these errors, having a wide effect on allocations and on the induced welfare they experience.

Continuity has its own strategic interpretation. Given that the data of a problem are never going to be known exactly and that some of them will have to come from the participants, a discontinuous rule is much more likely to be manipulable in undetectable ways.

We do not want to suggest that *continuity* should necessarily be imposed on rules. In fact, there are sometimes good reasons not to insist on it. In some settings, it is even unnatural. It is so for example in the bargaining model of Nash (1950). Depending upon which properties are already imposed on rules, it sometimes precludes taking advantage of possible Pareto improvements. Like all properties, *continuity* has a price, and we need to know what would be gained by dropping the requirement. By violating *continuity*, the Satterthwaite-Sonnenschein rules allow us to move away from dictatorship, but are their distributional properties that much better?

In any case, the issue of *continuity* is also orthogonal to the issue of *non-bossiness*. First, it is trivial to define rules that are *continuous* but violate *non-bossiness*. Conversely, there are rules that are *non-bossy* but violate *continuity*. Consider the following class of **money-and-object allocation problems**. A single object has to be assigned to one of several agents; there is also some amount of an infinitely divisible good, positive or negative—let us call it money—to be distributed. Designating by $\{0, 1\}$ the two-element set consisting of "not getting the object", and "getting the object", agents have **quasi-linear preferences** over the cross-product $\mathbb{R} \times \{0, 1\}$: this means that there is a uniquely defined maximal amount of money that, starting from *any* bundle not containing the object, the agent is willing to give up so as to obtain the object. This number is the agent's "valuation" of the object. Now, consider the **1st price rule**, defined as follows. For each preference profile, identify the agents whose valuation is the greatest. Select the one with the smallest index among them, assign the object to that agent and make him pay his valuation.

Thus, to the extent that the lack of attractiveness of the Satterthwaite-Sonnenschein rules is due to their discontinuous behavior, let us require of a rule that it be *continuous*, or as *continuous* as possible, not that it be *non-bossy*. More generally, let us include whatever forms of *continuity* seem most appropriate for the model under study in the list of properties whose cost in terms of others we need to study.

Summarizing this section, whether *non-bossiness* is interpreted as a mild form of *welfare dominance*, *consistency*, as an expression of the goal of fairness in distribution, or *continuity*, its distance to any one of these properties is too large for their normative underpinnings to contribute very meaningful arguments in its favor.

Experience has taught us that many of the requirements that we would like rules to satisfy are quite restrictive and that we should be ready to consider weaker forms—sometimes these forms have to be tailored to the model at hand—but these weaker forms should not exclude most of the circumstances in which the property makes sense. Unfortunately, that is the case for *non-bossiness*. Thus, these normative interpretations of *non-bossiness* are subject to the same limitations as the interpretations of *non-bossiness* as a strategic property.

6 Non-bossiness as a requirement of informational simplicity

The following passage develops another possible justification for *non-bossiness*. In essence, it says that for a rule to be "informationally simple", it should be *non-bossy*. It pertains to resource allocation. Although it does not seem to have been picked up by later writers, it raises a point that should be discussed.

> While we have not exhaustively considered this question, we have identified one substantial consideration that bears on non-bossiness's reasonableness and desirability. It relates to simplicity of design. Most allocation mechanisms, including the competitive mechanism, have equilibria that can simply and naturally be defined in terms of an adding up condition and some marginal equalities arising from the several agents' first-order conditions. Such mechanisms might appropriately be called first-order. They necessarily have the property that if several agents change their preferences, but maintain their initial marginal rates of substitution at their initial allocations, then the initial equilibrium is retained unchanged because the changes in preferences leave the adding up condition and marginal equalities intact. This, however, means that a bossy mechanism cannot be a first-order mechanism. Thus, *the simplicity of first-order mechanism can only be purchased at the cost of excluding bossy mechanisms from consideration* [our emphasis] (Satterthwaite and Sonnenschein, 1981, p.591)

Having applied a rule to some standard private good economy with convex preferences, let us imagine a change in the preference profile such that for each agent, his upper contour set at his assignment admits the same hyperplanes of support as initially. **Localness** of a rule says that in the new economy, it should choose the same allocation as the one it chose initially. If preferences are smooth, the hypothesis is that the change is such that each agent's unique hyperplane of support at his assignment remains the same. It is to this narrower class of situations that the term "first-order" that appears in the above quotation apparently refers. Conceptually, there does not seem to be a significant difference between *localness* and the *first-order property*, but let us consider smooth economies, a domain on which they are equivalent.

Of course, to explore the possibility of a logical relation between *localness* and *non-bossiness*, we need to work in a model in which both concepts are meaningful. Although *non-bossiness* can be expressed in any model, *localness* cannot; one should be able to talk about supporting hyperplanes. This is the case for classical models of allocation, or reallocation, of infinitely divisible goods. To fix the ideas, let us consider the classical model of reallocation of such goods.

In this model, there is no logical relation between the two properties. The Walrasian rule seems to be an easy example to use to make the point, but we should exercise care here because it is not in general *single-valued* whereas *non-bossiness* is a property of *single-valued* mappings. The requirement of *localness* is meaningful not only for rules, but also for correspondences. Whatever reasons we may have to be interested in it—Satterthwaite and Sonnenschein only name "simplicity"—seem to be independent of *single-valuedness*. Satterthwaite and Sonnenschein do not address the issue of *single-valuedness* and we presume that it is because the informational simplicity that they found attractive is meaningful for correspondences as well as for rules.

The Walrasian correspondence is clearly *local*. What about its *non-bossiness*?[18] For two goods, the situation is as follows. Suppose first that agent i is assigned a bundle that is not his endowment and that his preferences change. If at equilibrium, he is still assigned the same bundle, the equilibrium prices have to be the same. Thus, the other agents' budget sets are unchanged and they are still maximizing their preferences at the same bundles. If instead, at the initial equilibrium, agent i is assigned his endowment, it could be that after his preferences change, he is still assigned

[18]This discussion is based on Thomson (2014b).

his endowment but that the equilibrium prices change, resulting in different assignments for the other agents. This means that in the subeconomy obtained by removing him, there would be two equilibrium allocations, so on the domain to which this subeconomy would belong, the Walrasian rule is not *single-valued*. So, we could not talk about its *non-bossiness*.

If there are more than two goods, and even if agent i's initial assignment differs from his endowment, a change in his preferences may not affect his assignment and yet affect the other agents' assignments. (This is because the equilibrium prices may change in such a way that the agent's own budget set rotates around the segment defined by his endowment and his assignment. Whether that is compatible with uniqueness of Walrasian allocations is unclear.)

Appendix B shows a domain of quasi-linear economies on which the Walrasian correspondence is *single-valued* but violates *non-bossiness*. So, *localness* does not imply *non-bossiness*. The converse is not true either.[19] Appendix B also gives a rule that is *non-bossy* and not *local*.

Our conclusion here is that once again, if *localness* is the property that we really care about, that is the property that we should impose. Incidentally, *localness* is a very strong property, even if written for correspondences. Consider the classical model of reallocation of infinitely divisible goods, which is one of the models discussed by Satterthwaite and Sonnenschein, when preferences are smooth. Together with *efficiency* and the *individual-endowments lower bounds*, the requirement that a rule be invariant under certain contractions of lower contour sets at each chosen allocation, a sort of "dual" to *Maskin invariance*, which is obviously weaker than *localness*, only leads to the Walrasian allocations (Nagahisa, 1991; Nagahisa and Suh, 1995). The proof is in Appendix C.

In the many discrete models in which *non-bossiness* has been invoked, there is no counterpart to *localness*, so one could not make a case for *non-bossiness* on these grounds.

[19] There are domains on which the Walrasian correspondence is *single-valued* and *non-bossy*. An example is the domain of Cobb-Douglas economies. The Walrasian definition can also be applied to object-reallocation problems when each agent owns one object and consumes at most one (Shapley and Scarf, 1974). It is equivalent on this domain to Gale's "top-trading-cycle rule", which is *non-bossy*.

7 Beyond non-bossiness?

In this section, we explore ways of generalizing *non-bossiness*.

7.1 Group versions of non-bossiness

Many properties of allocation rules come in two versions, one for individuals and one for groups. For some, it is difficult to argue in favor of the individual version without at the same time making a case for the group version. Examples are the solidarity properties discussed above. When we require solidarity among a group of agents when their environment changes, we have to decide on the scope of the changes that are covered. If the change is one that affects agents' characteristics, we have to specify whether we allow the characteristics of only one agent to change or not. It can be argued that, when it is possible changes in preferences that are under discussion, there is no reason why we should limit the change of preferences to only one agent, and in fact, *welfare-dominance under preference replacement* is often written for changes in the preferences of an arbitrary set of agents. Similarly, when it is population that changes, it seems overly limiting to consider the departure or the arrival of only one agent, and here too, as usually formulated, the hypotheses of *population monotonicity* involve an arbitrary set of agents either leaving or arriving. For other properties, it does make a significant difference, analytically and behaviorally. *Strategy-proofness* is an example. Indeed, as already argued, the coordinated misrepresentations that *group strategy-proofness* is meant to make unprofitable are much less likely to occur than the individual misrepresentations that *strategy-proofness* is designed to prevent. Here are two possible versions of *non-bossiness* for groups.

1. The first version says that if a change in the preferences of the agents in a group does not cause a change in the assignment of any of its members, then it should not cause a change in anybody's assignment. This version is considered by Shenker (1992) and Barberà and Jackson (1995). Although it obviously implies *non-bossiness*, we are not aware of a rule that satisfies *non-bossiness* but not this version. So, a possible equivalence between the two properties is open.

2. A stronger and more interesting version says that if a change in the preferences of the agents in some group does not bring about a change in their *aggregate* assignment, then what each member of the complementary group is assigned should not change. To obtain a formulation that accom-

modates as wide a range of domains as possible, let us use the notation $\sum^*$ to designate any kind of mathematical aggregation of resources (summation, union, summations in some coordinates and unions in others).

Group non-bossiness: For each $R \in \mathcal{R}^N$, each $S \subset N$, and each $R'_S \in \mathcal{R}^S$, if $\sum_S^* \varphi_i(R) = \sum_S^* \varphi_i(R'_S, R_{N\setminus S})$, then $\varphi_{N\setminus N'}(R) = \varphi_{N\setminus N'}(R'_S, R_{N\setminus S})$.

When the problem under consideration is that of dividing a fixed bundle of resources that cannot be disposed of, saying that the aggregate assignment of the agents whose preferences change remains the same is equivalent to saying that the aggregate assignment of the complementary group does not change either. Thus, for such models, what we call *group non-bossiness* amounts to a weak form of a requirement that has been studied under the name of **separability** in various contexts: phrased in general terms, it says that if a change in some economy does not affect the aggregate assignment to some group of agents whose characteristics have not changed, then what each member of this group is assigned should not change. Moulin (1987)'s formulation of the principle is in the context of surplus sharing. There, each agent is characterized by a non-negative number, his "opportunity cost", and the issue is how to divide among all agents a surplus over the sum of their opportunity costs. The hypotheses of *separability* cover changes in both the opportunity costs of some agents and in the surplus. In a **claims problem** (O'Neill 1982), a group of agents have incompatible claims on a resource: the sum of their claims exceeds the amount available. Chun's formulation (1999) of the axiom for this class of problems is similar in that it covers simultaneous changes in some agents' claims and the endowment. In Chun (2006), agents are characterized by single-peaked preference relations defined over the non-negative reals. He considers simultaneous changes in the preferences of some agents and in the endowment that leave unchanged the aggregate assignment to the agents whose preferences are fixed. *Separability* says that what each of these agents is assigned should be unchanged.

Chun also proposes a version of this property obtained by keeping the endowment fixed. Let us refer to it as **fixed-resource separability**. In any model with fixed resources, it is this version that is equivalent to our second group version of *non-bossiness*. We noted earlier that *consistency* implies *non-bossiness*. It also implies *separability*, and therefore *fixed-resource separability*. Indeed, Chun's (1999) proof that for claims problems, *consistency* implies *separability*, is essentially model-free.

An **object** is an indivisible resource. A painting in an estate or an apartment listed in a university housing office are examples. The property considered by Pápai (2001a)[20] pertains to **object-allocation problems** when each agent may consume several objects and not all objects available need be assigned. It says that if, as a result of a change in an agent's preferences, the objects assigned to the others in total remain the same (this means that (i) he may now be assigned objects that were not assigned to any one initially and (ii) there may be objects that he was assigned initially but are not assigned to any one any more), then what each of the other agents is assigned should remain the same. Note that on the hypothesis side, no statement is made about how his welfare is affected, according to either one of the two preferences that are contemplated for him. So, this property can be seen as a one-person version of *fixed-resource separability.*

An open question is "when does *non-bossiness* imply *group non-bossiness*", parallel to the question "When does *strategy-proof* implies *group strategy-proofness*", addressed by Le Breton and Zaporozhets (2009) and Barberà, Berga, and Moreno (2010, 2014). We know that there is no general implication since in the context of one-to-one two-sided matching, the implication fails. However, there may be classes of models for which it does, or additional properties of allocation rules under which it holds. In the context of object allocation problems, it turns out to be equivalent to *non-bossiness* itself (Afacan, 2012). Identifying such classes, and such properties, appears to be a worthwhile research objective.

7.2 Non-bossiness for correspondences

As we stated it, and as it appears in the literature, *non-bossiness* is a property of *single-valued* mappings, which we call "rules". Does the idea apply to correspondences? The answer is yes, but even if the point of departure is our main definition (stated in physical terms), more than one formulation is possible:[21]

Let R, $i \in N$, and $R'_i \in \mathcal{R}$.

(i) Let $x \in \varphi(R)$ and $x' \in \varphi(R'_i, R_{-i})$. If at x and x', agent i's assignments are the same, then $x = x'$.

(ii) If at each of the allocations in $\varphi(R)$ and $\varphi(R'_i, R_{-i})$, agent i's as-

[20]Under the name of "total non-bossiness".

[21]One definition is proposed by Bogomolnaia, Deb, and Ehlers (2005).

signments are the same, then at each of these allocations, each of the other agents' assignments should be the same. This implies that for each of these two profiles, the correspondence actually selects a singleton.

(iii) Under the same hypothesis as in (ii), the sets of allocations that the correspondence selects should be the same.

(iv) We could also broaden the scope of the hypothesis and say that if at two allocations $x \in \varphi(R)$ and $x' \in \varphi(R'_i, R_{-i})$, agent i's assignments are the same, then the assignments to each other agent at x and x' should be the same too. This implies uniqueness of the allocation in $\varphi(R)$ whose i-th component is x_i and uniqueness of the allocation in $\varphi(R'_i, R_{-i})$ whose i-th component is x'_i.

In terms of the conceptual evaluation of *non-bossiness*, we do not see that it makes much of a difference whether we are dealing with rules or correspondences, and we mention these variants mainly for completeness.

7.3 Non-bossiness with respect to changes in other parameters

Can the *non-bossiness* idea can be formulated with respect to other parameters of an allocation problem?

1. In a claims problems, we can imagine a change in an agent's claim not being accompanied by a change in his award. The requirement that in such circumstances, the award to no other agent should be affected is satisfied by all commonly discussed rules. The property is implied by **others-oriented claims monotonicity**, which says that if an agent's claim increases, each of the other agents should receive at most as much as initially.

A notion of **pairwise** *non-bossiness* is considered by Ju (2013) in his study of a model that generalizes the classical claims problem in that a network is specified placing constraints on where claimants can receive compensation from. Here, the strategic opportunities of a pair of agents are not joint misrepresentation of preferences, but transfers of claims among themselves. The requirement is that if by so doing, the pair does not affect what they are assigned in total, then it should not affect the allocation. This is equivalent to the pairwise version of what we called *fixed-resource separability*.

2. Let us turn to changes in private endowments in a classical problem of fair division. If a change in an agent's endowment is not accompanied by a change in his assignment, then the aggregate assignment to the others

has to change, and it is not possible for the assignment to each of these agents to remain the same unless they are not all distributed (when the feasibility requirement is written as an equality). However, it still makes sense to require that the welfares of all of these agents should be affected in the same direction.

8 Against non-bossiness

In the previous sections, we have argued that the case for *non-bossiness* is rather weak. In this section, we go one step further and argue *against* the property. A rule allocates resources on the basis of their relative scarcity and abundance, as reflected by the entire profile of preferences. A change in an agent's preferences may affect the scarcity and abundance of goods in a way that may not call for a change in that agent's assignment, and yet may justify a change in the other agents' assignments. Our earlier discussion of the Walrasian rule should help in understanding these circumstances.

We have also claimed that if *non-bossiness* is to be given a strategic interpretation, it should be seen as a complement to *strategy-proofness*. Paradoxically, it sometimes gets in the way of *strategy-proofness*. The examples described next illustrates the point.

In an money-and-object allocation problem with quasi-linear preferences (Subsection 5.4), **Vickrey's rule** assigns the object to the agent who has the highest valuation—let us call him the "winner"—and makes him pay the second highest valuation. Each of the other agents receives no object and pays nothing. (If several agents have the highest valuation, a tie-breaking rule has to be invoked to determine the winner; the second highest valuation is also the highest valuation, and that is the price he pays.) When the second highest valuation varies between the highest valuation and the third highest valuation, the agent whose valuation is the second highest is not affected, but the price the winner pays is affected. Thus, the rule is bossy. Insisting on *non-bossiness* would deprive us of Vickrey's rule, which has been shown to be the only one to satisfy several sets of uncontroversial requirements.[22] The generalization of Vickrey's rule to a model in which preferences may not

[22]An example of such a characterization is based on the *individual-endowments lower bound*, *anonymity in welfare*, and *strategy-proofness* (Ashlagi and Serizawa, 2012). Related results are due to Saitoh and Serizawa (2008), Sakai (2008, 2012), and Chew and Serizawa (2007).

be quasi-linear, defined and characterized by Morimoto and Serizawa (2014), is *strategy-proof* too but it also violates *non-bossiness*. For task allocation problems, the Groves rules satisfy a number of attractive properties, but are bossy (Atlamaz and Yengin, 2008; Yengin, 2013a, 2013b).

We should note however that Vickrey's rule satisfies the version of *non-bossiness* that we introduced under the name of *subspace non-bossiness* (Item 7 of Section 2). What led to this property are mainly technical considerations but imposing it instead of *non-bossiness* has the merit of not disqualifying this important rule. In fact, an entire class of *strategy-proof* rules satisfying *subspace non-bossiness* but not *non-bossiness* itself can be defined (Nath and Sen, 2014).

Here are other rules that we have to forgo if we insist on *non-bossiness*. For priority-augmented object allocation problems[23], a main application of which is to school choice (Abdulkadiroğlu, and Sönmez, 2003), a natural counterpart of a rule that is central in the literature on one-to-one two-sided matching, the **tentative acceptance** rule[24], (Gale and Shapley, 1962), is *strategy-proof* but bossy. Here, we should note that it satisfies the weak form of *non-bossiness* introduced by Barberà, Berga, and Moreno (2014) (Item 5 in the list of Section 2). These authors advocate this property mainly on technical grounds in their search for a requirement that together with *strategy-proofness* would imply *weak group strategy-proofness*. The **immediate acceptance** rule[25] is *non-bossy* but that does little to enhance its attractiveness, as it is not *strategy-proof*, whereas its variant obtained by modifying the algorithm through which it is defined by requiring that at each step, no student applies to a school that has no remaining capacity (Alcalde, 1996) satisfies neither property (Harless, 2014).

For **object-reallocation problems** when preferences may exhibit indifference, classes of rules have been identified that are *efficient*, meet the *individual-endowment lower bound*, and are *strategy-proof*, but they all violate *non-bossiness* (Alcalde-Unzu and Molis, 2011; Jaramillo and Manjunath, 2012). In fact, no rule satisfies all four requirements (Bogomolnaia, Deb, and Ehlers, 2005; Jaramillo and Manjunath, 2012).

We have already seen that on certain domains of allocation problems in classical economies, the Walrasian rule is bossy (Appendix B). This rule is

[23]This is an object-allocation problem in which each object is equipped with a priority relation over its possible recipients.

[24]This rule is more commonly known as the "deferred acceptance mechanism" rule.

[25]This rule is more commonly known as the "Boston mechanism".

not *strategy-proof* but it certainly satisfies interesting properties.

Should we deprive ourselves of all of these rules by insisting on *non-bossiness*?

9 Summary and conclusion

We conclude with tables summarizing the logical relations that we have discussed, and with comments on the relevance of *non-bossiness* to axiomatic work, and in particular to axiomatizations.

In Table 1, we use the shorthand "group lie + transfer proofness" to refer to the property of immunity of a rule to misrepresentation by a group of agents of their preferences followed by ex post transfers of assignments among themselves. "Usually" refers to the assumption that disposing of resources is not allowed, and "most often" to the assumption that the reduction operation is transitive. The notation "sometimes" is left vague as the circumstances under which *strategy-proofness* and *non-bossiness* imply *group strategy-proofness* are still unclear, although conditions on domains are now known under which *strategy-proofness*, the weak form of *non-bossiness* presented as Item 5 of Section 2, and a weak form of *Maskin-invariance* together imply *weak group strategy-proofness* (Barberà, Berga, and Moreno, 2014).

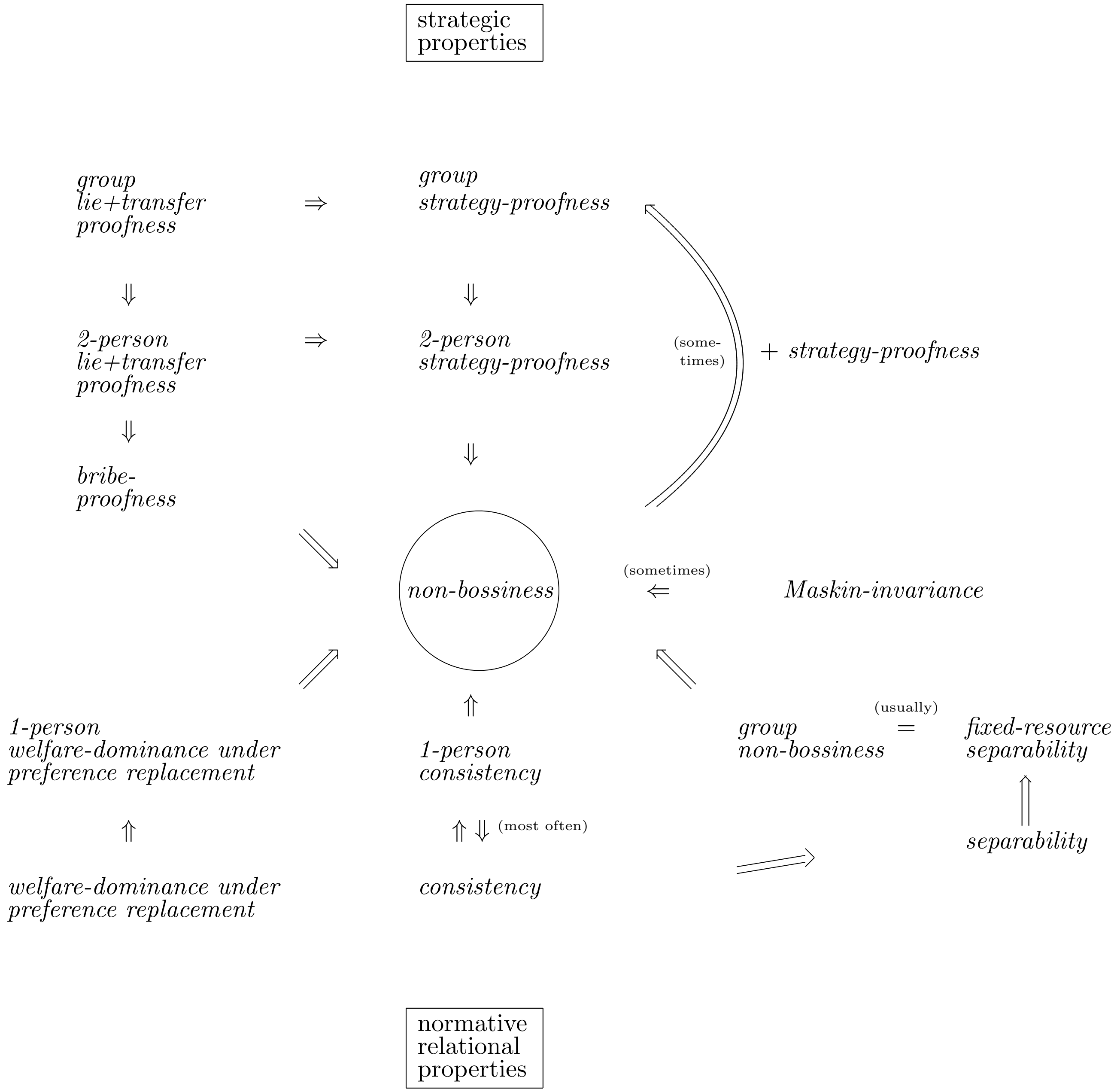

Figure 1: Table of logical relations between non-bossiness and various strategic (top half) and normative (bottom half) requirements.
1-person welfare-dominance = *welfare-dominance* when the preferences of only one person change
1-person consistency = *consistency* when only one person leaves

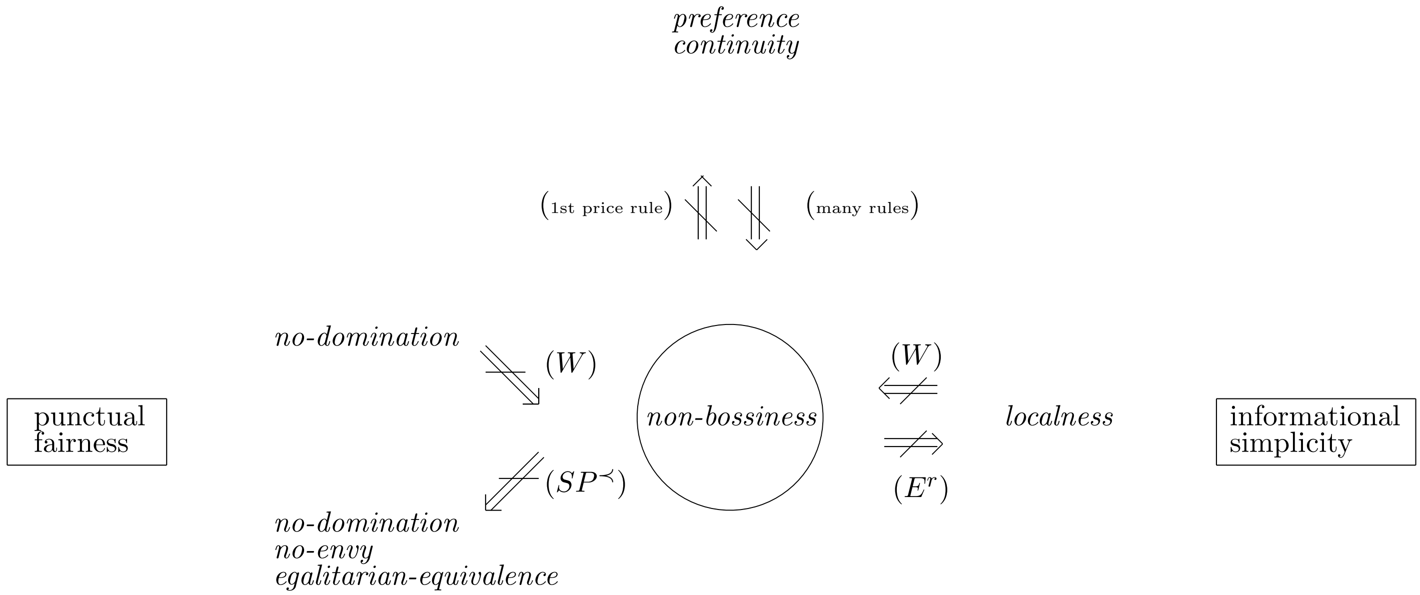

Figure 2: Table of logical relations between non-bossiness and other normative requirements. Next to a crossed arrow indicating that an implication fails, we name a rule that can serve to make the point.

The labels in Table 2 should be understood as follows: for classical exchange economies, $\boldsymbol{W}$ refers to the Walrasian rule; for classical fair division problems, $\boldsymbol{E^r}$ refers to the selection from the egalitarian-equivalence correspondence obtained by requiring the reference bundle to be in direction $r \in \Delta^{\ell-1}$; for object-allocation problems, $\boldsymbol{SP}^{\prec}$ refers to the sequential priority rule relative to order $\prec$; for money-and-object allocation problems, the **1st price rule** is the rule that assigns the object to the agent with the highest valuation and makes him pay his valuation; if there are several agents whose valuation is the highest, the agent with the smallest index among them is chosen.

It is always best to identify the weakest form of the axioms that precipitate the uniqueness part of a characterization, but if the rule that is characterized does not satisfy a natural strengthening of the property to which the logic of the justification inevitably leads, we can't help but feel dissatisfied. Specifically here, characterizing a rule on the basis of a list that includes *non-bossiness* certainly delivers a stronger uniqueness part than one based on a list that instead, includes the two-agent version of *group strategy-proofness*, *pairwise strategy-proofness*, but the strengthening is of little interest if the rule does not satisfy the latter property. The same comment applies to the possible normative interpretations of *non-bossiness* and the solidarity properties that we have seen imply *non-bossiness*.

The "if and only if" format of characterizations confuses the issue. We want to state the difficult part, which is almost always the uniqueness part, with the weakest forms of the properties that bring it about, as we should, but doing so often makes the other direction unsatisfactory, because it does not show the strongest forms of the properties that the rules that come out do satisfy.

In spite of the objections to *non-bossiness* that we have presented, two arguments can be made in favor of it.

1. When a rule violates *non-bossiness*, and because this property is implied by multiple others, it violates each of those. So, violations of *non-bossiness* can be understood as the root cause for its unsatisfactory behavior in these other dimensions. *Non-bossiness* being a sort of "common denominator" to several interesting properties, including it in axiomatic work sometimes sheds light on what connects a variety of rules and unites characterizations that otherwise would appear unrelated.[26]

2. It offers (hopefully temporary) technical help in solving difficult questions. We sometimes are unable to fully identify the implications of a list of properties that we care about. The dependence of each agent's assignment on the entire preference profile may be hard to figure out; the class of admissible rules may be too complex to describe. Imposing *non-bossiness* places structure on the class. Later, as our understanding of the subject develops, we may be able to make progress without invoking *non-bossiness*. That is what we should do.

10 Appendices

Appendix A

We list here (i) models for which *non-bossiness* and *strategy-proofness* together imply *group strategy-proofness*, (ii) models in which the implication holds when a stronger version of *non-bossiness* is imposed, (iii) models for which a related implication holds that involves some other requirements, and (iv) models for which *non-bossiness* and *strategy-proofness* together do not imply *group strategy-proofness*.

[26]Thus, from Kojima's (2010) result that, in the context of several-to-one two-sided matching, no selection from the stable correspondence is *non-bossy*, we can deduce the non-existence of selections from the stable correspondence satisfying each of the properties that we have enumerated imply *non-bossiness*.

(i) **Models for which non-bossiness and strategy-proofness together imply group strategy-proofness.**

(a) Allocating or reallocating bundles of infinitely divisible private goods, already mentioned in the main text.

(b) Allocating a social endowment of objects, when each agent consumes only one and is equipped with strict preferences over individual objects (Pápai, 2000b).

(c) Allocating a social endowment of objects, when each agent may consume several, and is equipped with preferences over sets of objects that are either size-monotonic (given two bundles containing different numbers of objects, the one with more objects is preferred), or inclusion-monotonic (given two bundles that are related by inclusion, the larger one is preferred) (Pápai, 2000a).

(d) Allocating a social endowment of objects among couples, when each couple receives only one, and each member of each couple is equipped with his or her own strict preferences over individual objects (Rhee, 2011).

(e) Allocating a single infinitely divisible good, when each agent is equipped with preferences that are strictly monotone in some interval, exhibit indifference to the left of that interval as well as to the right of that interval (Manjunath, 2012).

(f) Choosing the level at which a public good is produced, using a private good as input (Serizawa, 1996).

(ii) **For the next models, the implication holds if a stronger variant of non-bossiness is invoked.**

(g) Choosing one point along a one-dimensional continuum when preferences are single-dipped, *strategy-proofness* and *non-bossiness in welfare on the hypothesis side* (which is stronger than *non-bossiness*) imply *group strategy-proofness* (Manjunath, 2014). In the context of public choice, when there are no private goods, all agents consume the same thing, and a change in an agent's assignment when his preferences change means a change in everyone else's consumption, so *non-bossiness* is automatically satisfied. Thus, one would perhaps not expect that it would make much of a difference, but imposing *non-bossiness in welfare terms on the hypothesis side* instead of *non-bossiness* itself suffices to recover the implication.

(iii) **For other models, the implication holds if additional properties are imposed.**

(a) Choosing the 0-1 level of an excludable public good produced from one private good, when agents are equipped with preferences defined over $\mathbb{R}\times\{0,1\}$ that are quasi-linear. In this context if, in addition to *non-bossiness* and *strategy-proofness*, a rule satisfies two self-explanatory properties, **voluntary participation** and **no subsidy**, it is **weakly group strategy-proof** (Mutuswami, 2005): this means that it is immune to misrepresentations by a group that make each of its members better off. A similar implication holds with *non-bossiness in welfare on the hypothesis side*, the conclusion being that the rule is *group strategy-proof*.

(b) Fully allocating a social endowment of an infinitely divisible private good when preferences are single-dipped, *efficiency*, *non-bossiness on the conclusion side* (which is weaker than *non-bossiness*), and *strategy-proofness* together imply *group strategy-proofness* (Klaus, 2001a,b).

(iv) **Finally are models for which the implication fails.**

(a) Reallocating objects that are privately owned, when each agents is endowed with possibly several and is equipped with preferences defined over sets of objects (Pápai, 2003).

(b) Reallocating objects that are privately owned among agents each endowed with one object and equipped with preferences that may exhibit indifference (Alcalde-Unzu and Molis (2011); Jaramillo and Manjunath, 2012; Ehlers, 2014). (In this case, rules exist that are *non-bossy* and *strategy-proof*, but some of them are not even *pairwise strategy-proof*.)

(c) Reallocating objects organized in types, when each agent is endowed with one object of each type and is equipped with strict preferences defined over bundles consisting of one object of each type (Miyagawa, 1997).

(d) Fully allocating a social endowment of more than one infinitely divisible commodity among a group of agents equipped with commodity-wise single-peaked and peak separable[27] preferences (Morimoto, Serizawa, and Ching, 2013). In the one-commodity case, the so-called "uniform rule" is *group strategy-proof* (Sprumont, 1991). If there are more than one commodity, applying it commodity-wise delivers a rule that is *non-bossy* and *strategy-proof* but not *group strategy-proof*.

Appendix B

In this appendix we support our claim that there is no logical relation between *localness* and *non-bossiness*. We omit the formal definition of the

[27]This means that for each commodity, the maximizer of the relation with respect to the consumption of that commodity is independent of the amounts of the other commodities that are consumed together with it.

Walrasian rule. It is clearly *local*. However, there are domains on which it is bossy.

Claim 1 *The Walrasian rule violates non-bossiness on the quasi-linear domain.*

To prove this, we consider the following example, in the description of which $U(R_i, x_i)$ designates the upper contour set of the relation R_i at x_i. Here, by a quasi-linear relation we mean a relation such that if two bundles are indifferent, then so are the two bundles obtained from them by adding the same quantity of a particular good. Let $\boldsymbol{\mathcal{R}_{ql}}$ denote the class of continuous, monotonic, convex, and quasi-linear preferences for which the particular good is good 1. An economy is a pair (ω, R) of a profile $\omega \equiv (\omega_i)_{i\in N}$ of endowments and a profile $R \equiv (R_i)_{i\in N} \in \mathcal{R}_{ql}^N$. Let $\boldsymbol{W}$ denote the Walrasian rule. To make our point, we need not vary the endowment profile and therefore we do not list it as an argument of W.

Proof: Let $\ell = 2$, $N \equiv \{1, 2, 3\}$, $\omega_1 = \omega_2 = \omega_3 \equiv (5, 5)$, and preferences $R \in \mathcal{R}_{ql}^N$ be such that $U(R_1, x_1)$ is uniquely supported by the line of slope -1 at each point x_1 of ordinate 5, $U(R_2, x_2)$ is supported by any line of slope between -1 and $-\frac{1}{2}$ at each point x_2 of ordinate 3, $U(R_3, x_3)$ is supported by any line of slope between -1 and $-\frac{1}{2}$ at each point x_3 of ordinate 7. Let $y \equiv ((5, 5), (7, 3), (3, 7))$. We have $\{y\} = W(R)$. Now, let $R_1' \in \mathcal{R}_{ql}$ be such that $U(R_1', x_1)$ is uniquely supported by the line of slope $-\frac{1}{2}$ at each point x_1 of ordinate 5. Let $y_1' \equiv y_1$, $y_2' \equiv (9, 3)$, and $y_3' \equiv (1, 7)$. Let $y' \equiv (y_1', y_2', y_3')$. Then, $\{y'\} = W(R_1', R_2, R_3)$. Agent 1's assignment has not changed, but the other agents' assignments have. $\square$

Agents 2 and 3's preferences in the example used to prove the claim are not smooth: they have non-degenerate cones of lines of support at each point on the horizontal lines of ordinates 3 and 5 respectively. The relevance of smoothness in guaranteeing *non-bossiness* is discussed by Satterthwaite and Sonnenschein (1981).

Non-bossiness does not imply *localness*. The proof if by means of an example. It concerns the classical fair division problem when preferences belong to the domain $\boldsymbol{\mathcal{R}_{cl}}$ of continuous, monotonic, and strictly convex preferences.

Example 1 *Let r be a point in the simplex of commodity space, and let $\boldsymbol{E^r}$ be the rule that selects, for each economy, the efficient allocation x—under our assumptions, it is unique—such that, for some $\lambda \in \mathbb{R}_+$, each agent $i \in N$ is indifferent between x_i and λr.*

The **egalitarian-equivalence** correspondence (Pazner and Schmeidler, 1978) selects each allocation x such that there is a reference bundle x_0 that each agent finds indifferent to his assignment. The rules E^r are canonical selections from the Pareto–and–egalitarian-equivalence correspondence.

Claim 2 *For each $r \in \Delta^{\ell-1}$, the rule E^r is non local and non-bossy.*

Proof: It is obvious that each E^r violates *localness*. Now, let $R \in \mathcal{R}_{cl}^N$ and $x \equiv E^r(R)$ with associated parameter λ. Let $i \in N$. Let $R'_i \in \mathcal{R}_{cl}$ and $x' \equiv E^r(R'_i, R_{-i})$. Suppose that $x'_i = x_i$. Let λ' be the parameter associated with (R'_i, R_{-i}). We claim that $\lambda' = \lambda$. Indeed, if $\lambda' > \lambda$, each agent $j \in N \setminus \{i\}$ is better off than he was initially. This means that in R, x' Pareto dominates x. If $\lambda' < \lambda$, in (R'_i, R_{-i}), x Pareto dominates x'. In each case, we obtain a contradiction to the fact that E^r is a selection from the Pareto correspondence. If $\lambda' = \lambda$, for each $j \in N \setminus \{i\}$, $x'_j = x_j$. Altogether, $x' = x$. □

Because of its importance to public economics, let us also discuss the **Lindahl correspondence**, again omitting the formal definitions. (The only difference with the Walrasian correspondence is that agents face individualized prices.) It is clearly *local*. Also, there are interesting preference domains on which it is *single-valued* and *non-bossy*. One such domain is when (i) preferences are strictly convex and the public good is "strictly normal", in the sense that an increase in the individualized price an agent faces leads to an increase in the public good component of the bundle at which he maximizes his preferences in his budget set, and (ii) the technology is linear. Then, there is a unique Lindahl allocation. Now, if agent i's preferences change but his assignment does not, the public good level does not change. For an agent's maximizing bundle on his new budget set to have the same public good component, his budget set should be the same. He faces the same individualized prices. So then, the allocation remains a Lindahl allocation.

Appendix C

The **individual-endowments-lower-bound** correspondence selects all the allocations that each agent finds at least as desirable as his endowment.

Claim 3 *Any subsolution of the Pareto–and–individual-endowments-lower-bound correspondence that is local is a subsolution of the Walrasian correspondence.*

Proof: Let φ be a subsolution of the *Pareto*-and-*individual-endowments lower bound* correspondence. Let $R \in \mathcal{R}^N$, $x \in \varphi(R)$, and suppose that $x \notin W(R)$. Then, at the supporting prices p—they exist by *Pareto*—there is $i \in N$ such that $px_i < p\omega_i$. Then, let $R_i \in \mathcal{R}$ be such that $U(R'_i, x_i)$ still admits p as supporting princes, but $\omega_i \; P_i \; x_i$.[28] By *localness*, $x \in \varphi(R'_i, R_{-i})$. However, in (R'_i, R_{-i}), the *individual-endowments lower bound* is violated for agent i. □

[28]The argument applies even if preferences are not required to be strictly convex. If linear preferences were in the domain, it would suffice to give agent i preferences whose level curves are hyperplanes normal to the prices p.

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