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Research Paper

Secure implementability under Pareto-efficient rules in linear production economies with classical preferences☆

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ABSTRACT

This paper studies secure implementability (Saijo et al. (2007) "Secure Implementation," *Theoretical Economics* 2, pp.203–229) in linear production economies with classical preferences. Although secure implementability is in general stronger than the combination of strategy-proofness and non-bossiness (Satterthwaite and Sonnenschein (1981) "Strategy-Proof Allocation Mechanisms at Differentiable Points," *Review of Economic Studies* 48, pp.587–597), this paper shows that both properties are equivalent under Pareto-efficient rules in the economies. In addition, this paper characterizes securely implementable and Pareto-efficient rules in the economies when the number of agents is two.

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1. Introduction

This paper considers a linear production economy in which $n \geq 2$ agents consume $m \geq 2$ divisible and private goods on the basis of a linear production function. In the economy, this paper studies *secure implementability* (Saijo et al., 2007) defined as double implementability in dominant strategy equilibria and Nash equilibria.[1] Secure implementability is in general stronger than the combination of *strategy-proofness* and *non-bossiness* (Satterthwaite and Sonnenschein, 1981). In fact, Saijo et al. (2007) showed that secure implementability is in general equivalent to the combination of strategy-proofness

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[1] See Saijo et al. (2007) for a formal definition of secure implementability. By experiments, Cason et al. (2006) suggested that secure implementability might be a benchmark for constructing a mechanism that works well in practice.

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and the *rectangular property* (Saijo et al., 2007) which is in general stronger than non-bossiness.[2] This paper shows the equivalence between secure implementability and the combination of strategy-proofness and non-bossiness under Pareto-efficient rules in linear production economies with classical (continuous, strictly monotonic, and strictly convex) preferences. Precisely, this paper shows that the rectangular property is equivalent to non-bossiness under strategy-proof and Pareto-efficient rules in the economies. In linear production economies, Maniquet and Sprumont (1999) introduced the equal budget free choice rule and characterized it by strategy-proofness, Pareto-efficiency, and equal treatment of equals on the domain of classical preferences.[3] The result presented here implies that the equal budget free choice rule is securely implementable in linear production economies with classical preferences because it satisfies non-bossiness in addition to strategy-proofness and Pareto-efficiency.[4] In addition, this paper characterizes securely implementable and Pareto-efficient rules when the number of agents is two.

This paper is closely related to those of Kumar (2013) and Nishizaki (2014) for secure implementability. In production economies, Kumar (2013) showed that generalized serial cost sharing rules (Shenker, 1992) that is a generalization of the serial cost sharing rule (Moulin and Shenker, 1992) are securely implementable when the cost function is "convex" and the preferences are classical.[5] In contrast, this paper assumes that the cost function is "linear" and the preferences are classical. Because the equal budget free choice rule satisfies strategy-proofness which is a necessary condition for secure implementability in linear production economies, this paper investigates whether it is securely implementable in contrast to the study of Kumar (2013) in concave production economies. On the other hand, in pure exchange economies with Leontief utility functions, Nishizaki (2014) showed that secure implementability is equivalent to full implementability in truthful strategies (Nicolò, 2004) under non-wasteful (Li and Xue, 2013) rules. Precisely, Nishizaki (2014) showed that the rectangular property is equivalent to strong non-bossiness (Ritz, 1983) under strategy-proof and non-wasteful rules in the economies. Full implementability in truthful strategies is defined as the combination of strategy-proofness and strong non-bossiness which is in general weaker than the rectangular property and stronger than non-bossiness. Non-wastefulness requires efficient use of the redundant resources.

The remainder of this paper is organized as follows. Section 2 introduces the model presented here and Section 3 the properties of rules related to secure implementability. Section 4 demonstrates the results of this paper.

2. Model

Similar to Maniquet and Sprumont (1999), this paper considers a linear production economy with $n \geq 2$ agents and $m \geq 2$ divisible and private goods. Let $I \equiv \{1, \ldots, n\}$ be the set of *agents* and $K \equiv \{1, \ldots, m\}$ be the set of *goods*. For each $i \in I$ and each $k \in K$, let $y_{ik} \in \mathbb{R}_+$ be *consumption of good k for agent i* and $y_i \equiv (y_{ik})_{k \in K} \in \mathbb{R}_+^m$ be *consumption for agent i*. Let $y \equiv (y_i)_{i \in I} \in \mathbb{R}_+^{mn}$ be an *allocation*. In the model presented here, a good is produced from other goods by a technology that exhibits constant return to scale. For simplicity, let $Y \equiv \{y \in \mathbb{R}_+^{mn} | \sum_{i \in I} \sum_{k \in K} y_{ik} \leq 1\}$ be the set of *feasible allocations*.

A preference of an agent is represented by a binary relation defined on $\mathbb{R}_+^m$. For each $i \in I$, let R_i be a *preference for agent i* and I_i be the indifference relation associated with R_i. This paper assumes that each preference is *classical*, that is, continuous, strictly monotonic, and strictly convex.[6] For each $i \in I$, let $\mathcal{R}_i$ be the set of such preferences for agent i. Let $R \equiv (R_i)_{i \in I}$ be a profile of preferences and $\mathcal{R} \equiv \prod_{i \in I} \mathcal{R}_i$ be the set of profiles of preferences. For each $i \in I$, let $R_{-i} \equiv (R_h)_{h \in I \setminus \{i\}}$ be a profile of preferences other than agent i and $\mathcal{R}_{-i} \equiv \prod_{h \in I \setminus \{i\}} \mathcal{R}_h$ be the set of profiles of preferences other than agent i. In addition, for each $i, j \in I$, let $R_{-i,j} \equiv (R_h)_{h \in I \setminus \{i,j\}}$ be a profile of preferences other than agents i and j.

Agents collectively choose a feasible allocation according to a rule. Let $f : \mathcal{R} \to Y$ be a *rule* that associates a feasible allocation $y \in Y$ with a profile of preferences $R \in \mathcal{R}$.[7] For each $R \in \mathcal{R}$ and each $i \in I$, let $f_i(R)$ be the consumption for agent i at the allocation $f(R)$.

3. Properties of rules

Saijo et al. (2007, Theorem 1) characterized securely implementable rules by *strategy-proofness* and the *rectangular property* (Saijo et al., 2007). Strategy-proofness requires that the truthful revelation is a dominant strategy for the agent under

[2] See Mizukami and Wakayama (2017) for an alternative characterization of secure implementability in terms of restricted monotonicity (Mizukami and Wakayama, 2017) which is stronger than Maskin monotonicity (Maskin, 1977, 1999).

[3] Leroux (2004) showed that strategy-proofness is incompatible with Pareto-efficiency in non-linear (concave but not linear and not necessarily strictly concave) production economies with two divisible and private goods and the domain that contains the class of linear preferences. Shenker (1992) showed the same result in cost-sharing problems that include the model of Leroux (2004) as a special case.

[4] See Saijo et al. (2003), Saijo et al. (2007), Mizukami and Wakayama (2005), Mizukami and Wakayama (2017), Fujinaka and Wakayama (2008), Fujinaka and Wakayama (2011), Berga and Moreno (2009), Bochet and Sakai (2010), Nishizaki (2012), Nishizaki (2013), Nishizaki (2018), and Kumar (2013) for theoretical results on secure implementability.

[5] Saijo et al. (2007) showed an example of economies in which the serial cost sharing rule is securely implementable.

[6] Maniquet and Sprumont (1999) imposed continuity, strict monotonicity, and some richness condition but not necessarily strict convexity on the preferences.

[7] In this paper, a rule is defied as a direct revelation mechanism associated with a social choice function. This means that a rule is equivalent to a social choice function.

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