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Secure Implementability under Pareto-Efficient Rules in Linear Production Economies with Classical Preferences *

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Abstract

This paper studies secure implementability (Saijo, T., T. Sjöström, and T. Yamato (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, M. A. and H. 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.

Keywords: Secure Implementation, Dominant Strategy Implementation, Nash Implementation, Strategy-Proofness, Linear Production Economy.

JEL Classification: C72, D51, D52, D61, D71.

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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, Sjöström, and Yamato, 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, Sjöström, and Yamato (2007) showed that secure implementability is in general equivalent to the combination of strategy-proofness and the **rectangular property** (Saijo, Sjöström, and Yamato, 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,

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

[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, Sjöström, and Yamato (2003, 2007), Mizukami and Wakayama (2005, 2017), Fujinaka and Wakayama (2008, 2011), Berga and Moreno (2009), Bochet and Sakai (2010), Nishizaki (2012, 2013, 2017), and Kumar (2013) for theoretical results on secure implementability.

[5] Saijo, Sjöström, and Yamato (2007) showed an example of economies in which the serial cost sharing rule is securely implementable.

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 $y \equiv (y_i)_{i \in I} \mathbb{R}^{mn}_+$ 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 $\mathscr{R}_i$ be the set of such preferences for agent i. Let $R \equiv (R_i)_{i \in I}$ be a profile of preferences and $\mathscr{R} \equiv \prod_{i \in I} \mathscr{R}_i$ 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 $\mathscr{R}_{-i} \equiv \prod_{h \in I \setminus \{i\}} \mathscr{R}_h$ 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 $f \colon \mathscr{R} \to Y$ be a **rule** that associates a feasible allocation $y \in Y$ with a profile of preferences $R \in \mathscr{R}$. [7] For each $R \in \mathscr{R}$ and each $i \in I$, let $f_i(R)$ be the consumption for agent i at the allocation $f(R)$ under the rule f.

3 Properties of Rules

Saijo, Sjöström, and Yamato (2007, Theorem 1) characterized securely implementable rules by **strategy-proofness** and the **rectangular property** (Saijo, Sjöström, and Yamato, 2007). Strategy-proofness requires that the truthful revelation is a weakly dominant strategy for the agent under the rule. The rectangular property requires that if each agent does not gain or lose by changing the agent's revelation, then the allocation is not changed by the revelations of all the agents under the rule.

Definition 1. The rule f satisfies **strategy-proofness** if and only if for each $R, R' \in \mathscr{R}$ and each $i \in I$, $f_i(R_i, R'_{-i}) R_i f_i(R'_i, R'_{-i})$.

[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.

Definition 2. The rule f satisfies the **rectangular property** if and only if for each $R, R' \in \mathscr{R}$, if $f_i(R_i, R'_{-i}) I_i f_i(R'_i, R'_{-i})$ for each $i \in I$, then $f(R) = f(R')$.

Saijo, Sjöström, and Yamato (2007, Proposition 2) showed that the rectangular property is in general stronger than **non-bossiness** (Satterthwaite and Sonnenschein, 1981). [8] Non-bossiness requires that if the agent does not change the agent's consumption by changing the agent's revelation, then the allocation also is not changed by changing the agent's revelation under the rule.

Definition 3. The rule f satisfies **non-bossiness** if and only if for each $R, R' \in \mathscr{R}$ and each $i \in I$, if $f_i(R_i, R'_{-i}) = f_i(R'_i, R'_{-i})$, then $f(R_i, R'_{-i}) = f(R'_i, R'_{-i})$.

4 Results

For each $i \in I$ and each $r \in \mathbb{R}_+$, let $B_i(r) \equiv \{y_i \in \mathbb{R}^m_+ | \sum_{k \in K} y_{ik} \leq r\}$ be the **consumption set for agent *i* at *r***. For each $i \in I$, each $R_i \in \mathscr{R}_i$, and each $r \in \mathbb{R}_+$, let $m(R_i, B_i(r)) \equiv \{y_i \in B_i(r) | y_i R_i y'_i \text{ for each } y'_i \in B_i(r)\}$ be the set of most preferred consumption for agent i with R_i in the agent's consumption set $B_i(r)$. Similar to Maniquet and Sprumont (1999), we use the notation $m(R_i, r)$ as substitute for $m(R_i, B_i(r))$ for each $i \in I$, each $R_i \in \mathscr{R}_i$, and each $r \in \mathbb{R}_+$.

Remark 1. The set of most preferred consumption for each agent with each preference in the agent's consumption set is singleton because the preferences are classical.

In the model presented here, Maniquet and Sprumont (1999, Lemma 2) showed a feature of strategy-proof and Pareto-efficient rules.

Lemma 1 (Maniquet and Sprumont, 1999)**.** *If the rule f satisfies **strategy-proofness** and **Pareto-efficiency**, then for each $i \in I$, there is $a_i \colon \mathscr{R}_{-i} \to \mathbb{R}_+$ such that $f_i(R_i, R_{-i}) \in m(R_i, a_i(R_{-i}))$ for each $R \in \mathscr{R}$.* [9]

Remark 2. For Lemma 1, we know that $\sum_{i \in I} a_i(R_{-i}) = 1$ for each $R \in \mathscr{R}$ by the feasibility of allocations and Pareto-efficiency.

4.1 Secure Implementability under Pareto-Efficient Rules

The rectangular property is in general stronger than non-bossiness. In contrast, the following theorem shows that both properties are equivalent under strategy-proof and Pareto-efficient rules in linear production economies with classical preferences.

Theorem. *Suppose that the rule f satisfies **strategy-proofness** and **Pareto-efficiency**. If f satisfies **non-bossiness**, then f satisfies the **rectangular property**.*

[8] Precisely, Saijo, Sjöström, and Yamato (2007, Proposition 2) considered strong non-bossiness (Ritz, 1983) which is in general weaker than the rectangular property and stronger than non-bossiness. See Ritz (1983), Nicolò (2004), Mizukami and Wakayama (2005), Saijo, Sjöström, and Yamato (2007), Berga and Moreno (2009), and Nishizaki (2012, 2014, 2017) for theoretical results on this property and strategy-proofness.

[9] The rule f satisfies Pareto-efficiency if and only if for each $R \in \mathscr{R}$ and each $y \in Y$, if $y_i R_i f_i(R)$ for each $i \in I$, then $y_i I_i f_i(R)$ for each $i \in I$.

Proof. Let $R, R' \in \mathscr{R}$ be such that $f_i(R_i, R'_{-i}) I_i f_i(R'_i, R'_{-i})$ for each $i \in I$. Together with **strategy-proofness** and Remark 1, this implies that

$$f_i(R_i, R'_{-i}) = f_i(R'_i, R'_{-i}) \text{ for each } i \in I. \tag{1}$$

By Lemma 1, we know that for each $i \in I$, there is $a_i\colon \mathscr{R}_{-i} \to \mathbb{R}_+$ such that $f_i(R''_i, R''_{-i}) \in m(R''_i, a_i(R''_{-i}))$ for each $R'' \in \mathscr{R}$. Together with (1) and Remark 1, this implies that

$$m(R_i, a_i(R'_{-i})) = m(R'_i, a_i(R'_{-i})) \text{ for each } i \in I. \tag{2}$$

By (1), we know that $f_1(R_1, R'_{-1}) = f_1(R'_1, R'_{-1})$. Together with **non-bossiness**, this implies that

$$f(R_1, R'_{-1}) = f(R'_1, R'_{-1}). \tag{3}$$

This implies that $f_2(R_1, R'_2, R'_{-1,2}) = f_2(R'_1, R'_2, R'_{-1,2})$. Together with Remark 1, this implies that $m(R'_2, a_2(R_1, R'_{-1,2})) = m(R'_2, a_2(R'_1, R'_{-1,2}))$. Together with strict monotonicity of R'_2, this implies that $a_2(R_1, R'_{-1,2}) = a_2(R'_1, R'_{-1,2})$. Together with (2), this implies that $m(R_2, a_2(R_1, R'_{-1,2})) = m(R'_2, a_2(R_1, R'_{-1,2}))$. Together with Remark 1, this implies that $f_2(R_1, R_2, R'_{-1,2}) = f_2(R_1, R'_2, R'_{-1,2})$. Together with **non-bossiness**, this implies that

$$f(R_1, R_2, R'_{-1,2}) = f(R_1, R'_2, R'_{-1,2}). \tag{4}$$

By (3) and (4), we find that $f(R_1, R_2, R'_{-1,2}) = f(R'_1, R'_2, R'_{-1,2})$. By sequentially replacing R'_i by R_i for each $i \in I \setminus \{1,2\}$ in this manner, we find that $f(R) = f(R')$.

□

Securely implementability is characterized by strategy-proofness and the rectangular property. This implies that securely implementability is in general stronger than the combination of strategy-proofness and non-bossiness because the rectangular property is in general stronger than non-bossiness. In contrast, the above theorem implies that both properties are equivalent under Pareto-efficient rules in linear production economies with classical preferences.

Corollary 1. *When the rule f satisfies* ***Pareto-efficiency****, f is* ***securely implementable*** *if and only if f satisfies* ***strategy-proofness*** *and* ***non-bossiness****.*

In the model presented here, Maniquet and Sprumont (1999) introduced the equal budget free choice rule and characterized it by strategy-proofness, Pareto-efficiency, and equal treatment of equals. [10] On the basis of Corollary 1, we find that the equal budget free choice rule is securely implementable because this rule satisfies non-bossiness in addition to strategy-proofness and Pareto-efficiency. [11]

4.2 Characterization of Securely Implementable and Pareto-Efficient Rules in Two-Agent Case

When $n = 2$, Remark 2 implies that consumption for an agent is determined according to consumption for another agent under the strategy-proof and Pareto-efficient rule. On the basis of this relationship, we have the following corollary.

[10] The rule f is the equal budget free choice rule if and only if for each $R \in \mathscr{R}$ and each $i \in I$, $f_i(R) \in m(R_i, 1/n)$. The rule f satisfies equal treatment of equals if and only if for each $R \in \mathscr{R}$ and each $i, j \in I$, if $R_i = R_j$, then $f_i(R) I_i f_j(R)$.

[11] By definition, we find that consumption for each agent is not changed by changing another agent's revelation under the equal budget free choice rule. This implies that the equal budget free choice rule satisfies non-bossiness.

Corollary 2. *Suppose that $n = 2$. If the rule f satisfies **strategy-proofness** and **Pareto-efficiency**, then f satisfies **non-bossiness**.*

On the basis of Corollary 2, we find more feature of strategy-proof and Pareto-efficient rule when $n = 2$.

Lemma 2. *Suppose that $n = 2$. If the rule f satisfies **strategy-proofness** and **Pareto-efficiency**, then for each $i \in I$, there is $a_i \in \mathbb{R}_+$ such that $f_i(R_i, R_{-i}) \in m(R_i, a_i)$ for each $R \in \mathscr{R}$.*

Proof. By Lemma 1, we know that for each $i \in I$, there is $a_i \colon \mathscr{R}_{-i} \to \mathbb{R}_+$ such that $f_i(R''_i, R''_{-i}) \in m(R''_i, a_i(R''_{-i}))$ for each $R'' \in \mathscr{R}$. In what follows, we confirm that for each $i \in I$, $a_i(R_{-i}) = a_i(R'_{-i})$ for each $R_{-i}, R'_{-i} \in \mathscr{R}_{-i}$. Without loss of generality, let $i = 2$ and $R_1, R'_1 \in \mathscr{R}_1$ because $n = 2$. In addition, let $R_2 \in \mathscr{R}_2$.

If $f_1(R_1, R_2) = f_1(R'_1, R_2)$, then we find that $f_2(R_1, R_2) = f_2(R'_1, R_2)$ by **non-bossiness** due to Corollary 2. Together with Remark 1, this implies that $m(R_2, a_2(R_1)) = m(R_2, a_2(R'_1))$, that is, $a_2(R_1) = a_2(R'_1)$.

If $f_1(R_1, R_2) \neq f_1(R'_1, R_2)$ and $f_2(R_1, R_2) \neq f_2(R'_1, R_2)$, then we find that $a_2(R_1) \neq a_2(R'_1)$. Together with Remark 2, this implies a contradiction because $a_2(R_1) = 1 - a_1(R_2)$ and $a_2(R'_1) = 1 - a_1(R_2)$. This implies that $f_2(R_1, R_2) = f_2(R'_1, R_2)$ and $a_2(R_1) = a_2(R'_1)$ even if $f_1(R_1, R_2) \neq f_1(R'_1, R_2)$. □

On the basis of Remark 2 and Lemma 2, we can characterize strategy-proof and Pareto-efficient rules when $n = 2$.

Corollary 3. *Suppose that $n = 2$. The rule f satisfies **strategy-proofness** and **Pareto-efficiency** if and only if for each $i \in I$, there is $a_i \in \mathbb{R}_+$ such that $f_i(R_i, R_{-i}) \in m(R_i, a_i)$ for each $R \in \mathscr{R}$ and $\sum_{i \in I} a_i = 1$.*

On the basis of Corollaries 1 and 2, we have another result on secure implementability in linear production economies with classical preferences when $n = 2$.

Corollary 4. *Suppose that $n = 2$. When the rule f satisfies **Pareto-efficiency**, f is **securely implementable** if and only if f satisfies **strategy-proofness**.*

On the basis of Corollaries 3 and 4, we can characterize securely implementable and Pareto-efficient rules when $n = 2$.

Corollary 5. *Suppose that $n = 2$. The rule f is **securely implementable** and satisfies **Pareto-efficiency** if and only if for each $i \in I$, there is $a_i \in \mathbb{R}_+$ such that $f_i(R_i, R_{-i}) \in m(R_i, a_i)$ for each $R \in \mathscr{R}$ and $\sum_{i \in I} a_i = 1$.*

References

Berga, D. and B. Moreno (2009) “Strategic Requirements with Indifference: Single-Peaked versus Single-Plateaued Preferences,” *Social Choice and Welfare* 32, pp.275-298.

Bochet, O. and T. Sakai (2010) “Secure Implementation in Allotment Economies,” *Games and Economic Behavior* 68, pp.35-49.

Cason, T., T. Saijo, T. Sjöström, and T. Yamato (2006) “Secure Implementation Experiments: Do Strategy-Proof Mechanisms Really Work?” *Games and Economic Behavior* 57, pp.206-235.

Fujinaka, Y. and T. Wakayama (2008) “Secure Implementation in Economies with Indivisible Objects and Money,” *Economics Letters* 100, pp.91-95.

Fujinaka, Y. and T. Wakayama (2011) “Secure Implementation in Shapley-Scarf Housing Markets,” *Economic Theory* 48, pp.147-169.

Kumar, R. (2013) “Secure Implementation in Production Economies,” *Mathematical Social Sciences* 66, pp.372-378.

Leroux, J. (2004) “Strategy-Proofness and Efficiency are Incompatible in Production Economies.” *Economics Letters* 85, pp.335-340.

Li, T. and J. Xue (2013) “Egalitarian Division under Leontief Preferences,” *Economic Theory* 54, pp.597-622.

Maniquet, F. and Y. Sprumont (1999) “Efficient Strategy-Proof Allocation Functions in Linear Production Economies,” *Economic Theory* 14, pp.583-595.

Maskin, E. (1977) “Nash Equilibrium and Welfare Optimality,” mimeo, the revised version appeared in *Review of Economic Studies* 66 (1999) pp.23-38.

Mizukami, H. and T. Wakayama (2005) “Bossiness and Implementability in Pure Exchange Economies,” *RIMS Kokyuroku* 1461, pp.126-140.

Mizukami, H. and T. Wakayama (2017) “New Necessary and Sufficient Conditions for Secure Implementation,” *Economics Letters* 152, pp.76-78.

Moulin, H. and S. Shenker (1992) “Serial Cost Sharing,” *Econometrica* 60, pp.1009-1037.

Nicolò, A. (2004) “Efficiency and Truthfulness with Leontief Preferences. A Note on Two-Agent, Two-Good Economies,” *Review of Economic Design* 8, pp.373-382.

Nishizaki, K. (2012) “Secure Implementation in Queueing Problems,” *Theoretical Economics Letters* 2, pp.561-565.

Nishizaki, K. (2013) “An Impossibility Theorem for Secure Implementation in Discrete Public Good Economies,” *Economics Bulletin* 33, pp.300-308.

Nishizaki, K. (2014) “An Equivalence of Secure Implementability and Full Implementability in Truthful Strategies in Pure Exchange Economies with Leontief Utility Functions,” *Review of Economic Design* 18, pp.73-82.

Nishizaki, K. (2017) “Securely Implementable Social Choice Functions in Divisible and Nonexcludable Public Good Economies with Quasi-Linear Utility Functions,” *Journal of Public Economic Theory*, available online.

Ritz, Z. (1983) “Restricted Domains, Arrow-Social Welfare Functions and Noncorruptible and Non-Manipulable Social Choice Correspondences: The Case of Private Alternatives,” *Mathematical Social Sciences* 4, pp.155-179.

Saijo, T., T. Sjöström, and T. Yamato (2003) "Secure Implementation: Strategy-Proof Mechanisms Reconsidered," RIETI Discussion Paper 03-E-019.

Saijo, T., T. Sjöström, and T. Yamato (2007) "Secure Implementation," *Theoretical Economics* 2, pp.203-229.

Satterthwaite, M. A. and H. Sonnenschein (1981) "Strategy-Proof Allocation Mechanisms at Differentiable Points," *Review of Economic Studies* 48, pp.587-597.

Shenker, S. (1992) "On the Strategy-Proof and Smooth Allocation of Private Goods in Production Economies," Mimeo, PARC, Xerox Corporation, Palo Alto, CA.