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# Markets and Jungles

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# Markets and Jungles*

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**Abstract**

Economic institutions determine prospects for growth and development. In this paper a condition on the primitives determines whether an economy supports institutions that implement markets. Agents differ in land holdings, skill, and power. A competitive market assigns land to the skilled, not necessarily to the powerful. Therefore a market allocation needs to be robust to coalitional expropriation. More equally distributed power and higher congruence of land and power favor stable markets. Whether markets are stable forever in a dynamic setting, or alternate with expropriation in a limit cycle, decreasing efficiency and amplifying macroeconomic fluctuations, depends on social mobility, initial inequality, and the mismatch between demand and supply.
**Keywords:** Expropriation, market institutions, inequality, fluctuations, coalition formation.
**JEL:** E02, O43, C71.

## 1 Introduction

The quality of institutions interferes with the ability of markets to successfully assign scarce goods to individuals who can put them to their most productive use. Hence, as has been noted by North (1991) and a corresponding literature, institutions determine prospects for economic growth

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and development, for instance by way of the organization of production. Indeed, there appears to be some empirical support for this hypothesis, see e.g. Acemoglu et al. (2001) and Engerman and Sokoloff (2002).

Much of the existing literature on institutions and growth explicitly models particular, mostly political, institutions, such as elections, judicial enforcement or specialists for violence. It has been emphasized recently, for instance by Acemoglu and Robinson (2008) and Rajan (2009), that other types of institutions also affect the economic allocation. The correct set of institutions to be included in a model is, however, not obvious. Enforcement of property rights, for instance, has been observed under a variety of political institutions (relative stability of property rights under the dictatorships in South Korea and Chile are cases in point). Mulligan et al. (2004) do not observe any systematic economic or social policy differences between democracies and (non-communist) non-democracies across countries over the years 1960-90. Moreover, institutions may reinforce or cancel each other's effect on the economic allocation.

Therefore this paper departs from the usual approach and replaces potentially complex interactions of different institutions by a condition on the primitives determining whether a society supports market allocations. That is, the focus is on whether a market allocation can be implemented at all, rather than the specific institutions, such as executive or legislative powers, constitutions or behavioral norms, that might be employed to this end. Hence, the precise nature of interactions between different institutions of political, social, legal or economic kind need not be modeled. We are interested in the dynamic behavior of an economy when distributional concerns and expropriation constrain the economic interaction and thus the way production is organized. This is particular relevant when one seeks to explain macroeconomic phenomena such as output volatility, institutional or election cycles, or poverty traps.

To address these issues we use a simple dynamic model of overlapping generations. Agents differ in land holdings, skill, and power. Skill refers to individual productivity with land, and power to the extent to which individuals contribute to enforce particular allocations. Here power may be thought of as physical power, wealth, or status agents inherit from their ancestors. Agents are endowed with power; it does not depend on later consumption (as it does in Acemoglu et al., 2008b, 2009). The underlying economic problem consists in the organization of production, i.e. in whether

land is assigned to the skilled, which maximizes surplus, or to the powerful. Outcomes need to be robust to deviations to other allocation enforced by powerful coalitions. Admissible allocations contain the competitive land market allocation, and all conceivable redistributions of land to coalitions of agents, termed coalitional expropriation. A stability property determines which outcome is reached: an allocation is called stable if it is in an appropriate version of the largest consistent set (introduced by Chwe, 1994).[1]

Among coalitional expropriations the one assigning all land to the most powerful agents in the economy dominates all others. Versions of this assignment mechanism are well-known in the literature, e.g. the equilibria in the jungle Piccione and Rubinstein (2007), the pillage game (Jordan, 2006), or the dog bone economy in Sattinger (1993). As in our work, they require an equilibrium allocation to be stable to deviations by powerful coalitions. They differ from our approach, however, in that they look only at expropriation of consumption not of inputs, and they do not consider the market as an alternative allocation mechanism. Our focus lies on the organization of production, so we consider the possibility of expropriation of inputs rather than the one of expropriating profits[2] (which has been shown to often lead to underinvestment, see e.g. Besley and Ghatak, 2009). In our setting, stability of competitive markets in a given period is favored by more equal power endowment distributions and less mismatch between supply and demand, which increase the strength of market supporters, and implied by sufficient congruence of land and power.

In the long run two distinct patterns may emerge. In the first, allocation by markets is a stable outcome in every period, similar to the unique limit outcome in Cervellati et al. (2008); that is, markets are sustainable. Otherwise periods when a market allocation is a stable outcome alternate with periods when it is not, i.e. there is a limit cycle. In a limit cycle efficient assignment of land by markets contains the seed of its own undoing; the redistribution of power in the market causes coalitional expropriation in the next period. Depending on the distribution of market rents, in a limit cycle elites may be persistent (as in Acemoglu and Robinson, 2008) or not.

Whether economic institutions that permit resource allocation by mar-

[1] Also Acemoglu et al. (2009) use a version of the largest consistent set. In contrast to this paper they focus on a noncooperative foundation and abstract from production, evolution of power, and Condorcet cycles.

[2] Incorporating both and analyzing possible interdependencies is, though of course desirable, beyond the scope of the present paper and left to future research.

kets rather than expropriation are sustainable in the long run, depends on the characteristics of the economy, in particular on the way power transmits across generations. If power does not persist over generations, for instance when social mobility is high, markets are sustainable regardless of other parameters; that is, an ergodicity result holds. If an agent's power depends on the history of their entire lineage, for instance in a caste society, a limit cycle may emerge, causing distortions of the organization of production resulting in lower and more volatile output in the long run than when markets are sustainable. That is, the model is capable of explaining long run differences in total factor productivity across countries (cf. Banerjee and Moll, 2010). More equal initial period power distributions and less mismatch between demand and supply facilitate a regime of sustainable markets.

The results are consistent with a number of empirical observations. Higher growth rate volatility appears to be linked to inequality (Berg et al., 2008, Breen and García-Peñalosa, 2005), presence of social conflict (Rodrik, 1999), and to institutions proxied by settler mortality (Acemoglu et al., 2003). The dependence on initial distributions of power resembles the findings of Engerman and Sokoloff (2006). Also Acemoglu et al. (2008a) find in their study of Cundinamarca, Colombia, that their measure of inequality of political power is negatively related to economic development.

This paper is related to the field of institutional development. In this literature institutions are typically understood as the degree of property rights enforcement or extension of the suffrage in conjunction with specific political institutions or public policy.[3] This paper abstracts from modeling specific institutions, exclusively relying on stability of economic allocations.

A second, related field of literature studies stability of property rights in the presence of rent seeking.[4] These papers tend to emphasize efficiency losses due to waste of resources used to prepare and fight conflicts arising when property rights are not enforced. We use a different approach, in which contracts are enforced when the subsequent allocation is supported by sufficiently powerful agents, stressing distortions in the organization of production generated by a mismatch of skill and land.

Finally, this work links to studies on the relationship between inequality

[3]Some contributions following these approaches are e.g. Acemoglu and Robinson (2000), Acemoglu (2006), Acemoglu et al. (2005), Besley and Persson (2009), Cervellati et al. (2006, 2009), Galor et al. (2009), Gradstein (2004, 2007).

[4]See for instance Gonzalez (2007), Grossman (1991, 2001), Hafer (2006), Muthoo (2004), Tornell (1997).

and growth, especially those focusing on an institutional channel.[5] There inequality affects the choice of political institutions, determining in turn economic efficiency and prospects for growth. We are interested in the underlying conditions enabling a society to support market outcomes regardless of the particular mechanism employed to implement the allocation.

The paper is organized as follows. Section 2 outlines the static framework, section 3 contains the analysis of the static equilibrium. In section 4 we present the dynamic model. Section 5 concludes, and all proofs missing in the text are in the appendix.

# 2 Static framework

## 2.1 Agents

The economy is populated by a continuum of agents $I$, which is a compact subset of the real line endowed with unit Lebesgue measure. Agents live for one period only. An agent $i \in I$ is fully characterized by the tuple $(\theta_i, \lambda_i, \omega_i)$, representing productivity $\theta_i$, land holding $\lambda_i$, and physical power $\omega_i$. An agent is skilled, $\theta_i = \theta_H$, with exogenous probability $s$ and remains unskilled, $\theta_i = \theta_L$, otherwise. Assume that $1 < \theta_L < \theta_H$. Skills are distributed independently. An agent either holds a unit of land, $\lambda_i = 1$, or not, $\lambda_i = 0$.[6] Aggregate land endowment in the economy is given by $\ell \neq s$ (the case $\ell = s$ is a convex combination of the other two and not enlightening). Let $\lambda^0$ denote the initial land distribution in a period and $F(\omega, \lambda^0)$ the joint distribution of power and land endowments. We will frequently use $F(\omega, 1)$, respectively $F(\omega, 0)$, giving the measure of agents weaker than $\omega$ who are, respectively are not, endowed with land. Assume that the initial period marginal distribution function with respect to power is atomless. Lower and upper bounds of the support of the power distribution are denoted by $\underline{\omega}$ and $\overline{\omega}$. Agents derive linear utility from consumption.

## 2.2 Production

The economy produces a single consumption good. This occurs either using a subsistence technology requiring labor but not land, or using a composite

[5] See Alesina and Rodrik (1994), Grossman (1994), Persson and Tabellini (1994), Alesina and Perotti (1996) among others.

[6] Land can be also interpreted as a capital good that never depreciates and that cannot be accumulated.

technology that requires both labor and land. An agent's labor input is determined by effort choice $e_i$. Effort choice is not contractible. Provision of effort $e_i$ comes at a utility cost $e_i^2/2$. Using the composite technology output and thus consumption is given by $y = \theta_i e_i$. An agent chooses $e$ to maximize utility

$$\max_{e_i} r_i e_i - e_i^2/2,$$

where $r_i = 1$ if the agent is using the subsistence technology, and $r_i = \theta_i$ in case of the composite technology. Thus optimally $e_i = r_i$, and $r_i = 1$ if $\lambda_i = 0$ and $r_i = \theta_i$ if $\lambda_i = 1$, yielding output $y = r_i^2$. Hence, indirect utility $u(\theta_i, \lambda_i)$ depends on skill and land holdings: $u(\theta_i, 0) = 1/2$ and $u(\theta_i, 1) = \theta_i^2/2$. Output in the economy thus depends on the allocation of land and skill. If skill and land endowments $\lambda^0$ are uncorrelated, aggregate output is given by

$$y = \ell(s\theta_H^2 + (1-s)\theta_L^2) + (1-\ell).$$

Therefore redistributing land endowments to match the skill distribution, for instance through markets, increases output.

### 2.3 Timing

The timing of the model is the following:

- at stage 0 agents are born and nature draws types,
- at stage 1 land is assigned to agents,
- at stage 2 production and payoffs take place.[7]

### 2.4 Assignment of Land

The main economic concern in this model is the allocation of land among agents. This paper focuses on whether – given an initial endowment distribution of power and land – the assignment of land will be based on a *market for spot contracts* or occur through *coalitional expropriation*. On a spot market agents can contract on exchanges of land for labor, so that a competitive equilibrium allocation of land and labor is reached. On the other hand, land may be assigned by coalitional expropriation which may reach any redistribution of the land endowment among agents.

[7] That is, markets open only once, which precludes debt or rental contracts, and expropriation occurs before production. Letting markets and production open multiple times each period is beyond the present approach.

**Spot Market for Land**

The production technology implies that given the initial land distribution there are gains from trade prior to production. Therefore there are prices in units of the consumption good to ensure that both $(\theta_H, 0, .)$ agents are willing to buy and $(\theta_L, 1, .)$ agents are willing to sell land. Producing the required amount of the consumption good requires the buyer to exert labor effort so that in effect land is exchanged for labor. This is best interpreted as tenants who work the land until they are able to buy out their landlords.[8]

Determine now the market outcome. An agent $i$'s valuation for land is $u(\theta_i, 1) - u(\theta_i, 0) = (\theta_i^2 - 1)/2$. Demand for land at price $p$ is given by agents with $(\theta_i^2 - 1)/2 \geq p$ and supply by agents with $(\theta_i^2 - 1)/2 \leq p$. Hence, the market price for land is

$$p = \begin{cases} p_H = (\theta_H^2 - 1)/2 & \text{if } s > \ell \\ p_L = (\theta_L^2 - 1)/2 & \text{if } s < \ell \end{cases} \tag{1}$$

In the market equilibrium land allocation $(\lambda)$ all possible matches between high skill and land are realized. Land is rationed uniformly among indifferent agents. An agent $i$ obtains payoff

$$(\lambda_i(\theta_i - 1) + 1)^2/2 - (\lambda_i - \lambda_i^0)p,$$

where $\lambda_i^0$ denotes land endowment and $\lambda_i$ land holding after the market has taken place. Denote a Walrasian market allocation of land in this economy by $W(\lambda^0)$ where $\lambda^0$ is the initial land distribution. $W(\lambda^0)$ is given by an allocation $((\lambda_i)_{i \in I}, p)$ such that

$$\begin{aligned} &\theta_i = \theta_H \Rightarrow \lambda_i = 1 \text{ if } s < \ell \text{ and} \\ &\theta_i = \theta_L \Rightarrow \lambda_i = 0 \text{ if } s > \ell, \end{aligned} \tag{2}$$

and an associated market price $p$ given by (1). Agents' payoffs are completely determined by the initial land distribution $\lambda^0$ and measures $s$ and $\ell$. Note that $W(\lambda^0)$ does not pin down a unique land distribution, since agents on the longer market side are indifferent between buying and selling. All allocations in $W(\lambda^0)$ are, however, payoff equivalent.

[8] Another interpretation is that the buyer pays the price for land in arrears – this requires enforceability of a relational loan contract between seller and buyer, however. Note also that perfect capital markets are consistent with the setup.

**Coalitional Expropriation**

As outlined above define coalitional expropriation as any redistribution of land from the endowment distribution $\lambda^0$. Land distributions resulting from coalitional expropriation are required to provide every agent with at most one unit of land and to have aggregate land $\ell$.

In an allocation $(\lambda, e, p) = ((\lambda_i, e_i)_{i\in I}, 0)$, where $p = 0$ as a convention, resulting from coalitional expropriation, $e_i = \theta_i^2$ if $\lambda_i = 1$ and $e = 1$ if $\lambda_i = 0$. Note that this setup remains silent on the exact means of expropriation; it is consistent for instance with violent theft, or discrimination codified in law or laid down in social norms. In case of coalitional expropriation an exchange of land for labor is not admissible since land is assigned by expropriation, so that agents' payoffs are $\theta_i^2/2$ if $\lambda_i = 1$ and $1/2$ if $\lambda_i = 0$.

## 2.5 Admissible Allocations

We limit our attention to allocations that are induced by a market equilibrium or coalitional expropriation. This ignores market allocations with non-Walrasian prices inducing some form of rationing.[9] Define the set of admissible of allocations accordingly as follows.

**Definition 1 (Admissible Allocations)** *An allocation $(\lambda, e, p)$ is admissible if*

*(i)* $\int_{i\in I} \lambda_i di = \ell$ *and* $\lambda_i \in \{0; 1\}$ *for all* $i \in I$ *(feasibility) and*

*(ii)* $e_i = \theta_i$ *if* $\lambda_i = 1$ *and* $e_i = 1$ *if* $\lambda_i = 0$*, (incentive compatibility).*

*(iii) either* $p = 0$ *or it is a Walrasian allocation, i.e.* $(\lambda, p) \in W(\lambda^0)$.

Since effort choices fully depend on land allocations we drop effort $e$ when referring to allocations and only write $(\lambda, p)$. Definition 1 contains three important assumptions. First, redistribution does not waste resources. This is because we focus on allocative distortions as a consequence of expropriation rather than on waste. Second, only deterministic redistribution is

[9]The main effect of considering such allocations is adding the possibility for sellers to extract market rents from buyers when the latter are less powerful. This would have no effect when $\ell < s$ as the entire rent goes to the sellers anyway. If $\ell > s$ this facilitates the emergence of limit cycles, since less powerful buyers do not receive any rents, which yields persistent elites, see Proposition 7.

considered.[10] Third, since effort provision cannot be forced, for instance due to lack of observability, we consider allocations that result from voluntary exchanges of labor for land on a spot market, but we do not consider allocations requiring gifts or forced labor.

### 2.6 Solution Concept

Our aim is to identify a distribution of resources that is robust to potential coalitional deviations to other admissible allocations. Given such a resource allocation production takes place, which in turn determines agents' payoffs. Denote an agent's payoff from an allocation $(\lambda, p)$ by

$$v(\lambda^0, \theta_i, \lambda_i, p) = (\lambda_i(\theta_i - 1) + 1)^2/2 - (\lambda_i - \lambda_i^0)p.$$

We model coalitional deviations as a move to another admissible allocation enforced by a coalition preferring the new allocation met with opposition by a coalition preferring the status quo. Given an allocation $(\lambda^b, p^b)$ there is a coalitional deviation to an allocation $(\lambda^a, p^a)$ if there is a power majority of agents that strictly prefers $(\lambda^a, p^a)$ to $(\lambda^b, p^b)$. In the spirit of von Neumann and Morgenstern (1944) we say $(\lambda^a, p^a)$ *dominates* $(\lambda^b, p^b)$.

**Definition 2 (Dominance)** *An allocation $(\lambda^a, p^a)$ dominates an allocation $(\lambda^b, p^b)$, that is $(\lambda^a, p^a) \succ (\lambda^b, p^b)$, if $\int_{i\in C} \omega_i di > \int_{i\in C'} \omega_i di$ where $C = \{i \in I : v(\lambda_i^0, \theta_i, \lambda_i^a, p^a) > v(\lambda_i^0, \theta_i, \lambda_i^b, p^b)\}$ and $C' = \{i \in I : v(\lambda_i^0, \theta_i, \lambda_i^a, p^a) < v(\lambda_i^0, \theta_i, \lambda_i^b, p^b)\}$.*

Hence, an allocation $a$ dominates an allocation $b$ strict winners under $a$ (coalition $C$) have greater aggregate power than strict losers under $a$ (coalition $C'$). $C$ and $C'$ are uniquely determined by the payoffs in the respective allocations. Strict preference is required since winners and losers may need to communicate and coordinate. Hence, introducing a small but positive coordination cost does not alter the results, and thus the use of force to change allocations is consistent with the setup, as is non-violent regime change. To familiarize the reader with the concept suppose $a = W(\lambda^0)$ and $b = (\lambda^0, 0)$. If $W(\lambda^0) \neq (\lambda^0, p)$ competitive allocations dominate the endowment allocation, that is $a \succ b$. This is because $C' = \emptyset$ as trade is voluntarily, and, since

[10] Admitting stochastic redistribution requires commitment to enforce the outcome. Then supporting a market allocation becomes considerably more difficult. Moreover, when capital market frictions are sufficiently severe, stochastic expropriation may lead to higher output than assignment by markets (e.g. Gall, 2008, pursues this point).

$\theta_i$ is drawn independently, a positive measure of agents has strict gains from trade, so that $C \neq \emptyset$.

As noted by von Neumann and Morgenstern (1944) transitivity of the relation $\succ$ is not guaranteed. In our setting this may indeed be the case implying that the core is empty and a stable set does not exist, see the appendix for an example. Therefore we use an appropriate version of the largest consistent set introduced by Chwe (1994). Define now the relation indirect (or farsighted) dominance for our framework.

**Definition 3 (Indirect Dominance)** *Allocation $(\lambda^a, p^a)$ indirectly dominates allocation $(\lambda^b, p^b)$, that is $(\lambda^a, p^a) \succcurlyeq (\lambda^b, p^b)$, if there exist admissible $(\lambda^1, p^1)$, $(\lambda^2, p^2)$, ..., $(\lambda^m, p^m)$ (where $(\lambda^1, p^1) = (\lambda^a, p^a)$ and $(\lambda^m, p^m) = (\lambda^b, p^b)$) such that for every $j = 2, ..., m$ $(\lambda^{j-1}, p^{j-1}) \succ (\lambda^j, p^j)$ and $(\lambda^1, p^1) \not\prec (\lambda^j, p^j)$.*

That is, for allocation $a$ to indirectly dominate allocation $b$ there must be a sequence of allocations starting at $b$, such that each element in the sequence (i) directly dominates each predecessor if there is one and (ii) does not dominate the final allocation $a$.[11] Intuitively, at each step a power majority must be willing to change allocation, while there must not be a power majority preferring the present allocation over the final allocation and thus willing to veto the re-allocation. Define consistent sets accordingly as follows.

**Definition 4 (Consistent Set)** *A set of admissible allocations $Y$ is consistent if $(\lambda^a, p^a) \in Y$ if and only if for all admissible $(\lambda^b, p^b)$ with $(\lambda^b, p^b) \succ (\lambda^a, p^a)$ there exists $(\lambda^c, p^c) \in Y$ where $(\lambda^c, p^c) \succcurlyeq (\lambda^b, p^b)$such that $(\lambda^a, p^a) \not\prec (\lambda^c, p^c)$. Define the largest consistent set $\bar{Y}$ as a consistent set with $Y \subseteq \bar{Y}$ for all consistent $Y$. An allocation $(\lambda, p)$ is said to be* stable *if it is in the largest consistent set, $(\lambda, p) \in \bar{Y}$.*

Consistency requires that any deviation from an allocation $a$ in the consistent set to another allocation $b$ dominating $a$ in turn enables a deviation to another allocation $c$ that (indirectly) dominates $b$ and is in the consistent set, but does not dominate $a$. Intuitively, this postulates that for any deviation from allocations in the consistent set agents anticipate to return to an

[11] In contrast to Chwe (1994) we only require the final allocation to be undominated. Here the dominance relation relies on all winners and losers, and requires relative power majority. Requiring strict dominance of the final allocation thus means that indirect implies direct dominance and a consistent set need not exist, see appendix for an example.

allocation in the consistent set not dominating the original allocation. Thus the deviation is deterred. $\bar{Y}$ is then the largest set of admissible allocation that is consistent and therefore encompasses all allocations supportable as stable outcomes. A particular concern is whether a Walrasian allocation induced by markets is in the largest consistent set, since this ensures that once a market is in place any potential deviations can be credibly deterred. Therefore we refer to allocations in the largest consistent set as *stable*. Thus a society can support a market allocation only when it is in the largest consistent set, for instance through adequate political or legal institutions such as a constitution guaranteeing property rights and a market economy. Otherwise any such institution will be vulnerable to coalitional deviations.

Although the largest consistent set is non-empty under weak conditions existence is not straightforward, since our dominance relation only uses relative power majority. The next section provides existence and uniqueness results that enable the dynamic analysis further below.

# 3 Static Equilibrium

## 3.1 Coalitional Expropriation: the Jungle Emerges

Start by defining a cutoff power endowment $\hat{\omega}$ to characterize measure $\ell$ of the most powerful agents:

$$\hat{\omega} : \mu(i \in I : \omega_i > \hat{\omega}) = \ell,$$

where $\mu(.)$ denotes the Lebesgue measure. Let $(\lambda^E, 0)$ denote a admissible allocation with $\lambda_i^E = 1$ if $\omega_i > \hat{\omega}$ and $\lambda_i^E = 0$ if $\omega_i < \hat{\omega}$. A useful result follows immediately.

**Proposition 1 (Expropriation)** *The allocation* $(\lambda^E, 0)$ *is unique a.e. and undominated by all admissible allocations* $(\lambda', 0)$.

*Proof:* Consider a admissible allocation $(\lambda', 0)$. Note that $v(\lambda_i^0, \theta_i, \lambda_i^E, 0) > v(\lambda_i^0, \theta_i, \lambda_i', 0)$ iff $i \in C = \{i \in I : \lambda_i' = 0 \wedge \lambda_i^E = 1\}$, and $v(\lambda_i^0, \theta_i, \lambda_i^E, 0) < v(\lambda_0, \theta_i, \lambda_i', 0)$ iff $i \in C' = \{i \in I : \lambda_i' = 1 \wedge \lambda_i^E = 0\}$. Hence, $(\lambda^E, 0) \not\succ (\lambda', 0)$ if

$$\int_{i \in C} \omega_i di \geq \int_{j \in C'} \omega_j dj. \tag{3}$$

Now $\mu(i \in I : \lambda_i' = 1 \wedge \lambda_i^E = 0) = \mu(i \in I : \lambda_i' = 0 \wedge \lambda_i^E = 1)$ as both allocations are admissible. Therefore $\mu(i \in C) = \mu(i \in C')$. Since $\lambda_i^E = 1 \Leftrightarrow \omega_i \geq \hat{\omega}$

and $\lambda_i^E = 0 \Leftrightarrow \omega_i \leq \hat{\omega}$, $\omega_i \geq \omega_j$ for all $i \in C$ and $j \in C'$. This implies (3). Uniqueness a.e. follows immediately from the definition of $\hat{\omega}$ and the assumption that $F(\omega)$ is atom-less. □

This means there is a unique land distribution $\lambda^E$ not dominated by any coalitional redistribution. This allocation is characterized by expropriation of the weak by the strong, that is the economy becomes a jungle. $(\lambda^E, 0)$ will be referred to as *allocation under expropriation* in the remainder of the paper. There are several reasons for singling out expropriation among a continuum of admissible coalitional expropriations. First, expropriation does not require coordination. Second, it assigns land only by power (contrary to the market, which assigns land by skill only). Third, it has become a recurrent theme in the literature under various guises.[12]

### 3.2 Stable Outcomes in the Static Economy

Let $(\lambda^M, p^M)$ denote a market allocation. Clearly, by Proposition 1 $(\lambda^E, 0) \succ (\lambda^M, p^M)$ implies $\bar{Y} = (\lambda^E, 0)$. If the reverse holds and $(\lambda^M, p^M) \succ (\lambda, 0)$ for all admissible coalitional expropriations $(\lambda, 0) \neq (\lambda^E, 0)$, $\bar{Y} = (\lambda^M, p^M)$. Otherwise the relation $\succ$ is not transitive, however, and there is a coalitional expropriation $(\lambda, 0) \neq (\lambda^E, 0)$ with $(\lambda, 0) \succ (\lambda^M, p^M)$, but $(\lambda^M, p^M) \succ (\lambda^E, 0)$. In this case the largest consistent set includes $(\lambda^M, p^M)$, $(\lambda^E, 0)$, and a particular coalitional expropriation $(\lambda^X, 0)$ with $(\lambda^M, p^M) \not\succ (\lambda^X, 0)$ and $(\lambda^X, 0) \not\succ (\lambda^M, p^M)$. Existence of $(\lambda^X, 0)$ is warranted by continuity of the measure of the agent space. When $F(\omega)$ is atom-less, $(\lambda^X, 0) \succ (\lambda, 0)$ for all coalitional expropriations $(\lambda, 0)$ with $(\lambda, 0) \succ (\lambda^M, p^M)$. The details of the proof can be found in the appendix and allow the following statement.

**Proposition 2** *If $(\lambda^M, p^M) \succ (\lambda^E, 0)$, where $(\lambda^M, p^M) \in W(\lambda^0)$, a spot market for land is stable, $(\lambda^M, p^M) \in \bar{Y}$. Otherwise only an allocation under expropriation is stable, $\bar{Y} = (\lambda^E, 0)$.*

Hence, whether spot markets for land are stable, that is whether a society can support markets, depends only on the dominance relation between the market and the jungle. $(\lambda^M, p^M) \succ (\lambda^E, 0)$ together with Proposition 1 imply that all admissible allocations are either directly or indirectly dominated

[12] For instance the jungle equilibrium in Piccione and Rubinstein (2007), the pillage game equilibrium in Jordan (2006), and the dog bone economy in Sattinger (1993).

by $(\lambda^M, p^M)$. A discussion of conditions implying $(\lambda^M, p^M)$ is the unique element of the largest consistent is postponed to the next section. Determine now conditions for $(\lambda^M, p^M) \succ (\lambda^E, 0)$ using the definition of $\succ$. Two cases arise depending on the market price for land. Indeed, $(\lambda^M, p^M) \succ (\lambda^E, 0)$ if and only if

$$\int_{\underline{\omega}}^{\hat{\omega}} \omega_i dF(\omega_i, 1) + s \int_{\underline{\omega}}^{\hat{\omega}} \omega_i dF(\omega_i, 0) > \int_{\hat{\omega}}^{\overline{\omega}} \omega_i dF(\omega_i, 0) \text{ if } p = p_L, \tag{4}$$

$$\int_{\underline{\omega}}^{\hat{\omega}} \omega_i dF(\omega_i, 1) + (1-s) \int_{\hat{\omega}}^{\overline{\omega}} \omega_i dF(\omega_i, 1) > \int_{\hat{\omega}}^{\overline{\omega}} \omega_i dF(\omega_i, 0) \text{ if } p = p_H. \tag{5}$$

That is, a market allocation is stable if the aggregate power of the winners from markets (LHS) exceeds the one of the losers from markets (RHS). Indeed, weak agents endowed with land ($\omega_i < \hat{\omega}$ and $\lambda_i^0 = 1$) always support markets, since they are expropriated in the jungle. Moreover, agents that can realize gains from trade support markets. Their identity depends on the market price $p$. When the land price is low, weak skilled buyers ($\theta_i = \theta_H$ and $\lambda_i^0 = 0$) obtain rents and support markets, see condition (4). If the market price is high, all unskilled sellers ($\theta_i = \theta_L$ and $\lambda_i^0 = 1$) obtain rents on the market and support markets, see condition (5). The RHS of both conditions captures the power of strong agents not endowed with land ($\omega_i > \hat{\omega}$ and $\lambda_i^0 = 0$). They strictly prefer expropriation, since they obtain land for free in the jungle.

### 3.3 Properties of the Stable Outcome

Some observations are worth mentioning at this point. Whether a market is stable depends on the mismatch between demand and supply in the market and on properties of the joint distribution of land and power such as inequality or correlation. When the mismatch between demand and supply is lower we observe an increase in the support for market allocations, because the power of either weak skilled buyers or strong unskilled sellers increases.

Moreover, a more equal power distribution should favor stability of markets. This is because more equality decreases the power of strong agents without land and increases the power of weak agents with land. The effect of more equality is less pronounced in a high price environment, since it also decreases the power of unskilled strong landholders who support markets.

To see that correlation of land and power plays an important role, suppose for a moment that the most powerful agents hold land (i.e. $\lambda_i^0 = 1 \Leftrightarrow$

$\omega_i > \hat{\omega}$) and land and power are perfectly correlated. Then the market allocation is a stable outcome (indeed the only one), as the RHS of the appropriate condition (4) or (5) is zero, while some agents have strict gains from trade, so that the LHS of the respective condition is strictly positive. This is particularly interesting if one is concerned about a dynamic setting, since the jungle concentrates land among the powerful generating perfect correlation in next period's endowments.

This reasoning extends to more general cases. Formalize the correlation between land and power by defining indicator variables $P(i) = I_{\omega_i \geq \hat{\omega}}$ returning 1 if agent $i$ has power $\omega_i \geq \hat{\omega}$ and 0 otherwise, and $L(i) = \lambda_i^0$. Both $P$ and $L$ return 1 with probability $\ell$.[13] The correlation coefficient

$$\rho = \frac{\text{cov}(P, L)}{\sqrt{\text{var}(P)\text{var}(L)}},$$

describes congruence of land and power in the endowment distribution. Indeed sufficient congruence stabilizes markets, as stated in the following summary proposition (details can be found in the appendix).

**Proposition 3** *Properties of the stable outcome:*

*(i) When $s > \ell$ ($s < \ell$) a decrease (increase) of $s$ favors markets as a stable outcome, i.e. $(\lambda^M, p^M) \in \bar{Y}$.*

*(ii) Suppose that $\underline{\omega} < \hat{\omega}$, i.e. the distribution of power is non-degenerate for $\omega \leq \hat{\omega}$, and expropriation is the only stable outcome ($(\lambda^E, 0) \succ (\lambda^M, p^M)$). Then there is a redistribution of power from the strong ($\omega_i > \hat{\omega}$) to the weak ($\omega_i < \hat{\omega}$) favoring stability of market allocations.*

*(iii) There is $\epsilon > 0$ such that for all $\rho \geq 1 - \epsilon$ a market allocation is the stable outcome.*

### 3.4 Markets as the Unique Stable Outcome

Since the set of stable outcomes may not be a singleton, it is of interest which circumstances imply that markets are not only a stable outcome but also the only one. This occurs if the market allocation dominates all other admissible

[13] Under our assumptions on the agent space, $(I, \mathcal{B}(I), \mu)$, where $\mathcal{B}(I)$ denotes the Borel sigma algebra on $I$, is a measure space and $P$ and $L$ are measurable functions mapping $I$ into $\{0; 1\}$. The distributions of $P$ and $L$ are thus given by $G_P(P = X) = \mu(i \in I : P(i) = X)$ and $G_L(L = X) = \mu(i \in I : \lambda_i^0 = X)$.

allocations. This in turn is true if and only if – given parameters – markets dominate the optimal coalitional expropriation to attack markets. Such an optimal coalitional expropriation exists and is well-defined: an admissible distribution of land $\lambda'$ that maximizes the difference between the power of agents strictly preferring $(\lambda', 0)$ and the power of those strictly preferring a market allocation. Then, if markets dominate $(\lambda', 0)$, markets also dominate any other coalitional expropriation. The following lemma characterizes such an optimal coalitional expropriation.

**Lemma 1 (Optimal Coalitional Expropriation)** *There is an optimal coalitional expropriation* $(\lambda', 0)$ *characterized by*

- *if* $\ell < s$*:* $\lambda'_i = 1$ *if* $\omega_i > \widetilde{\omega}$ *and* $\lambda^0_i = 0$ *or* $\lambda^0_i = 1$ *and* $\theta_i = \theta_H$*,*
- *if* $\ell > s$*:* $\lambda'_i = 1$ *if* $\omega_i > \widetilde{\omega}$ *and* $\lambda^0_i = 1$ *or* $\lambda^0_i = 0$ *and* $\theta_i = \theta_L$*, or if* $\omega_i > \widetilde{\omega}/2$ *and* $\lambda_i = 0$ *and* $\theta_i = \theta_H$*,*

*with* $\widetilde{\omega}$ *implicitly defined by* $\mu(i \in I : \lambda'_i = 1) = l \vee \widetilde{\omega} = 0$*.*

*Proof:* In Appendix.

Intuitively, the optimal coalition to attack markets assigns land to the agents with the highest marginal contribution to that coalition's power against market supporters. Hence, agents who switch strict preference for markets to coalitional expropriation when bribed with land are assigned double the weight of agents who switch to or from indifference only. Agents whose preferences do not depend on whether they obtain land are never assigned land, see appendix for an example. Figure 1 shows the optimal expropriation for $\ell > s$ where $\lambda'$ is the land distribution under expropriation.

A market allocation is the unique stable outcome if the market dominates optimal coalitional expropriation, that is if

$$\int_{\underline{\omega}}^{\widetilde{\omega}} \omega_i dF(\omega_i, 1) + s\int_{\underline{\omega}}^{\widetilde{\omega}/2} \omega_i dF(\omega_i, 0) > \int_{\widetilde{\omega}}^{\overline{\omega}} \omega_i dF(\omega_i, 0) + s\int_{\widetilde{\omega}/2}^{\widetilde{\omega}} \omega_i dF(\omega_i, 0), \quad (6)$$

in case $\ell > s$ and therefore $p = p_L$. Otherwise, if $\ell < s$ the condition is

$$\int_{\underline{\omega}}^{\widetilde{\omega}} \omega_i dF(\omega_i, 1) + (1 - s)\int_{\widetilde{\omega}}^{\overline{\omega}} \omega_i dF(\omega_i, 1) > \int_{\widetilde{\omega}}^{\overline{\omega}} \omega_i dF(\omega_i, 0). \quad (7)$$

Conditions (6) and (7) are versions of conditions (4) and (5). Closer inspection reveals that Proposition 3 can be generalized to state that a market

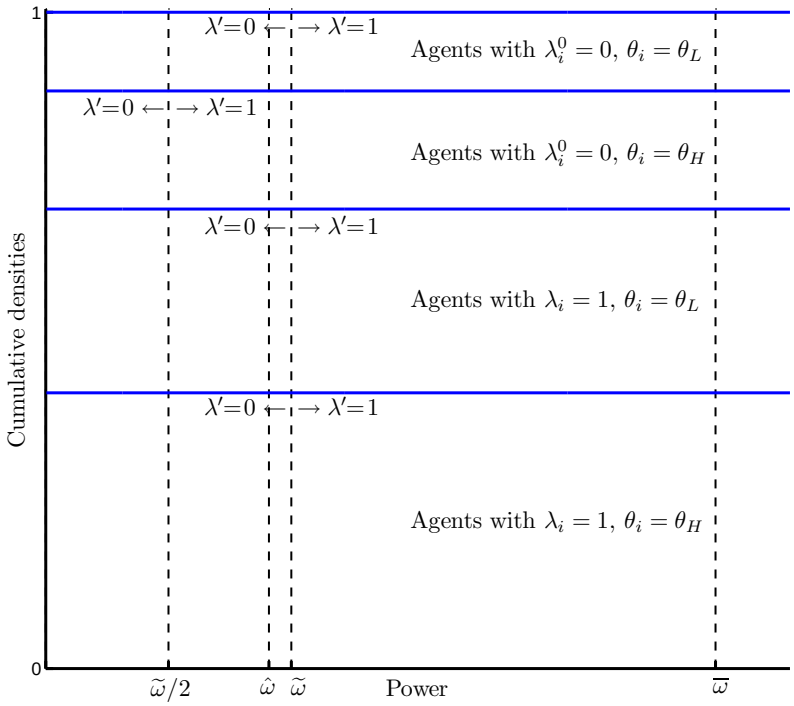


Figure 1: Optimal coalitional expropriation when $\ell > s$.

allocation is the unique stable outcome if the mismatch between demand and supply is low and the correlation of land and power is sufficiently strong. Although a more elaborate redistribution may be needed the second part of Proposition 3 generalizes in case $\ell > s$, for $\ell < s$ an additional qualifier has to require that $s$ is sufficiently high.

# 4 Dynamic Setting

Consider now a dynamic version of the model outlined above. Each generation of agents lives for a single period. In a period $t$ agents are born and nature draws types, then land is assigned, finally production takes place and output is consumed, as above. Each agent has a single child. Absent investment generations are linked by bequests of land and intergenerational spill-overs of power and consumption. As land does not depreciate, parents leave their land to their offspring. The power of an agent's offspring is determined both by the parent's power *and* consumption obeying the rule

$$\omega_{i,t+1} = \alpha\omega_{i,t} + \beta y_{i,t}, \tag{8}$$

where $\alpha, \beta \geq 0$. This law of motion merits some explanation. It states that agents' power is an aggregate of their parent's power and consumption. This allows for a number of interpretations. Power may be thought of as *wealth* in the consumption good.[14] Power may also be viewed as a *physical characteristic* that is at least partly acquired through early childhood investments linked to consumption such as health. Finally, power may be interpreted as *social status* of a dynasty acquired through ancestors' consumption. In all cases $\alpha$ measures the persistence of power and $\beta$ the impact of parental consumption. These parameters reflect the degree of social mobility in a society. When e.g. $\alpha = 0$, an agent's power is fully determined by parental success measured by income, reflecting a society that imposes no barriers of transition between its social or power strata, possibly interpretable as a meritocracy. For the opposite extreme consider $\beta = 0$, implying that an agent's power is determined entirely by the initial period power of that agent's dynasty, which is best interpreted as a society with little permeability between its social and power strata, such as feudalism or a caste system.

Proposition 2 ensures that always the jungle or the market is a stable outcome of the static model. As there may be multiple allocations in the largest consistent set, in this case the allocation that is implied by the assignment mechanism generating the previous period's allocation is selected. That is, the status quo assignment mechanism is selected whenever it can be justified as stable. Define a period *equilibrium allocation* by the allocation of the status quo assignment mechanism if it is in the largest consistent set, otherwise by the unique stable allocation. This is well-defined as only expropriation or the market allocation can be unique stable allocations, and both are stable whenever multiplicity arises. To close the model let expropriation be the status quo in period 0.

### 4.1 Transition Functions

Key to the model's long run dynamics is the mapping of period $t$'s joint distribution of land and power into period $t+1$'s joint distribution of land and power. This mapping is well defined since under our selection rule an equilibrium allocation fully determines next period's endowments through the consumption spill-over and the bequest of land.

Under expropriation the level of consumption is either $\theta_i^2$ if $\omega_{i,t} > \hat{\omega}_t$, or

[14] This is consistent with warm glow preferences; for instance, when agents' utility from consumption $c$ and bequest $b$ is $u(c,b) = c^\gamma b^{1-\gamma}$ and storage costless, then $\alpha = \beta = \gamma$.

1 otherwise. Power in period $t+1$ is then

$$\omega_{i,t+1} = \alpha\omega_{i,t} + \beta \begin{cases} \theta_i^2 & \text{if } \omega_{i,t} > \hat{\omega}_{i,t} \\ 1 & \text{if } \omega_{i,t} < \hat{\omega}_{i,t}. \end{cases}$$

Since land goes to the powerful, the land distribution in period $t+1$ is

$$\lambda_{i,t+1} = \begin{cases} 1 & \text{if } \omega_{i,t} \geq \hat{\omega}_{i,t} \\ 0 & \text{if } \omega_{i,t} < \hat{\omega}_{i,t}. \end{cases}$$

Note that under expropriation $\omega_{i,t} > \hat{\omega}_{i,t}$ implies $\omega_{i,t+1} > \hat{\omega}_{i,t+1}$. Therefore

$$\int_{\hat{\omega}_{t+1}}^{\overline{\omega}_{t+1}} \omega_i dF_{t+1}(\omega_{i,t+1}, 0) = 0.$$

In a market consumption is $\theta_i^2$ if the agent owns land at the beginning and at the end of the period, 1 if he never owns the land, $\theta_i^2 - p$ if he buys and $1+p$ if sells. Hence, power in period $t+1$ is

$$\omega_{i,t+1} = \alpha\omega_{i,t} + \beta(\lambda_{i,t}\theta_i^2 - (\lambda_{i,t} - \lambda_{i,t}^0)p + (1 - \lambda_{i,t}))$$

For the land distribution in period $t+1$ note that landholders either buy land on the market or inherit it. For $p_t = p_L$ land supply must exceed demand by skilled agents, that is $\ell > s$, and the market allocation assigns land to all skilled agents and uniformly rations the excess supply to the unskilled. An unskilled agent's probability to obtain land on the market $q_t^L$ is given by

$$q_t^L = \frac{\ell - s}{1 - s}.$$

Since $q_t^L$ does not depend on $t$ we drop the time subscript. $\lambda_{i,t+1}$ is given by

$$\lambda_{i,t+1} = \begin{cases} 1 & \text{if } \theta_{i,t} = \theta_H \\ \begin{cases} 1 \text{ with prob. } q^L \\ 0 \text{ with prob. } 1 - q^L \end{cases} & \text{if } \theta_{i,t} = \theta_L. \end{cases}$$

Hence, land is distributed randomly among the unskilled.

A similar reasoning applies when $\ell < s$ and thus $p_t = p_H$. All unskilled agents sell their land on the market, while the skilled are indifferent. At price $p_H$ there is excess demand and land is rationed uniformly to the skilled. Denote a skilled agent's probability to obtain land on the market by $q_t^H$.

$$q_t^H = \frac{\ell}{s}.$$

Dropping again the time subscript and writing $q^H$, $\lambda_{i,t+1}$ is given by

$$\lambda_{i,t+1} = \begin{cases} 0 & \text{if } \theta_{i,t} = \theta_L \\ \begin{cases} 1 \text{ with prob. } q^H \\ 0 \text{ with prob. } 1 - q^H \end{cases} & \text{if } \theta_{i,t} = \theta_H. \end{cases}$$

This means that land is distributed randomly among the skilled.

### 4.2 Long Run Behavior

The transition functions derived above determine the dynamic pattern of allocations in the model economy. We shall be especially concerned with the question of whether markets are sustainable over time, or whether income inequality generated by a market outcome today will preclude stability of markets tomorrow. Indeed in the long run two distinct patterns can emerge. The first is sustainable markets, when spot markets for land are stable in every period. The second is a limit cycle, when stable markets alternate with unstable markets in regular intervals.

It will be useful to determine the relation of a period $t$ equilibrium allocation to its period $t+1$ counterpart. Note that an allocation under expropriation in period $t$ implies a market is stable in $t+1$ by Proposition 3. This is since the strongest agents get land and higher income than expropriated agents in $t$. Thus the power ranking is preserved and the strongest agents' offspring will be among the strongest in $t+1$. Since they already hold land, there is no profit in expropriating again. Moreover, a positive measure of agents has gains from trade in a market.

Suppose land is allocated by a market in period $t$. Stability of a market in $t+1$ depends on whether period $t+1$ endowments resulting from a market allocation in $t$ are sufficiently equal, on whether $s$ is sufficiently close to $\ell$, and on the correlation of land and power (see Proposition 3). Making heavy use of the independence of both skill distribution and uniform rationing we are able to state the following, the details are in the appendix.

**Proposition 4** *Suppose a market is an equilibrium allocation in period $t$. A market is stable in period $t+1$ if*

$$\alpha E_t(\omega) - \beta\phi_1(s,\ell) \leq \phi_2(s,\ell)\alpha E_t(\omega|\omega < \hat{\omega}_t),$$

*where $\phi_1$ and $\phi_2$ are functions with $\phi_1(s,\ell) > 0$ and $\phi_2(s,\ell) > 1$ that increase (decrease) in $\ell$ and decrease (increase) in $s$ if $s > \ell$ ($s < \ell$).*

Proposition 4 implies immediately that stable markets spawn stable markets if power is distributed sufficiently equally in $t$, or if $\alpha$ is sufficiently small while $\beta > 0$. The following proposition gives a similar condition for a market today to generate expropriation tomorrow, the details are in the appendix.

**Proposition 5** *Suppose a market is an equilibrium allocation in period $t$. Expropriation is the only stable outcome in period $t+1$ if*

$$\alpha E_t(\omega) - \beta\psi_1(s,\ell) \geq \psi_2(s,\ell)\alpha E_t(\omega|\omega < \hat{\omega}_t),$$

*where $\psi_1$ and $\psi_2$ are functions with $\psi_1(s,\ell) > 0$ and $\psi_2(s,\ell) > 1$ that increase in $\ell$ and decrease (increase) in $s$ if $s > \ell$ ($s < \ell$).*

When $\beta$ is small enough, sufficient inequality of power in $t$ implies that expropriation is the $t+1$ equilibrium. Indeed stability of markets in the long run depends on whether markets induce sufficiently equal power distributions over time. The next proposition gives conditions that ascertain whether markets are stable forever or alternate with expropriation in a limit cycle, its proof can be found in the appendix.

**Proposition 6 (Long Run Behavior)** *(i) Suppose the condition in Proposition 4 holds in a period $t_0$. Markets are stable in every period $t > t_0$ if*

$$\kappa_1(\ell,\theta_H) + \kappa_2(s,\ell,\theta_L,\theta_H)\alpha \geq 0,$$

*where $\kappa_1(.) > 0$ and $\kappa_2(.) < 0$ are differentiable functions that increase (decrease) in $\ell$ and decrease (increase) in $s$ if $s > \ell$ ($s < \ell$).*
*(ii) Suppose the condition in Proposition 5 holds and markets are an equilibrium allocation in a period $t_0$. If $\alpha$ is sufficiently great and $\beta > 0$, expropriation is stable in every period $t_0 + 2\tau - 1$, and a market is stable in every period $t_0 + 2\tau$ for $\tau = 1, 2, ...$*

Proposition 6 contains three important statements. First, as in the static version above, sustainable markets become more likely as the initial power distribution becomes more equal and $\ell$ or $s$ adjust to reduce mismatch of demand and supply of land. Moreover, an ergodicity result holds: Propositions 4 and 6 imply that markets will be eventually stable forever, independently of the initial power distribution when $\alpha$ is sufficiently small and $\beta > 0$. That is, if persistence of power in a dynasty is sufficiently low, a regime of sustainable markets will eventually emerge. This is because, for $\alpha$ small, a

market redistributes sufficient power to agents who hold land at the end of the period, and thus enables stable markets in the next period. Less mismatch of demand and supply tends to further facilitate the redistribution of power by markets.

On the other hand, part (ii) of the above proposition and Proposition 5 imply that sufficient power inequality in some period may indeed lead to limit cycles of expropriation, in particular when persistence of power is high, but also when $s > \ell$ and $s$ sufficiently close to 1, see appendix for the details. Both impede the market's ability to redistribute power by way of rent sharing through prices.

Whether markets are sustainable may have important implications for social mobility in an economy as a market allocates resources by productivity, whereas an allocation under expropriation is based on historic outcomes. Hence, our next concern is intergenerational social mobility. When markets are sustainable, independent draws of skill ensure that rents are distributed equally in the long run. This need not be the case when the economy alternates between market and expropriation. Indeed elites may be persistent, that is offspring of agents who are powerful will be powerful in all future periods. This is the case if landowners obtain a sufficiently high share of the rents when a market is stable.

**Proposition 7** *Elites are persistent, i.e. for all $i, j \in I$ $\omega_{i,t} > \hat{\omega}_t > \omega_{j,t}$ implies $\omega_{i,t+2} > \hat{\omega}_{t+2} > \omega_{j,t+2}$, if markets and expropriation alternate for all $t$ and either (i) $\ell < s$, or (ii) $\ell > s$ and $(1+\alpha)\theta_L^2 > \theta_H^2 + \alpha$.*

*Proof:* Let $t$ denote a period when markets are unstable. Choose $i, j \in I$ so that $\omega_{i,t} > \hat{\omega}_t > \omega_{j,t}$. Expropriation in $t$ implies $\omega_{i,t+1} \geq \alpha\omega_{i,t} + \beta\theta_L$ and $\omega_{j,t+1} = \alpha\omega_{i,t} + \beta$. In period $t+1$ markets must be stable so that

$$\omega_{i,t+2} \geq \alpha\omega_{i,t+1} + \beta \begin{cases} (\theta_L^2+1)/2 & \text{if } s < \ell \\ (\theta_H^2+1)/2 & \text{if } s > \ell \end{cases} \quad \text{and}$$

$$\omega_{j,t+2} \leq \alpha\omega_{i,t+1} + \beta \begin{cases} \theta_H^2 - (\theta_L^2-1)/2 & \text{if } s < \ell \\ (\theta_H^2+1)/2 & \text{if } s > \ell. \end{cases}$$

Clearly, $\omega_{i,t+2} > \hat{\omega}_{t+2} > \omega_{j,t+2}$ if $\omega_{i,t+2} > \omega_{j,t+2}$ for all $i, j \in I$ with $\omega_{i,t} > \hat{\omega}_t > \omega_{j,t}$. Using the expressions from above, $\omega_{i,t+2} > \omega_{j,t+2}$ if

$$\alpha^2\omega_{i,t} + \alpha\beta\theta_L^2 + \beta\frac{\theta_L^2+1}{2} > \alpha^2\omega_{j,t} + \alpha\beta + \beta\left(\theta_H^2 - \frac{\theta_L^2-1}{2}\right) \text{ if } s < \ell,$$

$$\alpha^2\omega_{i,t} + \alpha\beta\theta_L^2 + \beta\frac{\theta_H^2+1}{2} > \alpha^2\omega_{j,t} + \alpha\beta + \beta\frac{\theta_H^2+1}{2} \text{if } s > \ell.$$

This establishes the statement. □

Moreover, a limit cycle of markets alternating with expropriation induces output fluctuations. Aggregate output in a period $t$ when a market is stable is given by

$$y_t^M = 1 + \begin{cases} s(\theta_H^2 - \theta_L^2) + \ell(\theta_L^2 - 1) & \text{if } s < \ell \\ \ell(\theta_H^2 - 1) & \text{if } s > \ell \end{cases}$$

When expropriation is stable in period $t$, output is independent of whether land is scarce or not:

$$y_t^E = 1 + s\ell(\theta_H^2 - \theta_L^2) + \ell(\theta_L^2 - 1).$$

Clearly, $y_t^M > y_t^E$. Therefore Propositions 4, 5, and 6 link inequality in endowments and income to output efficiency and fluctuations through the assignment of land. When volatility of output in periods $t = t_0 + 1, t_0 + 2, ...$ is measured by $var(y_t - y_{t-1})$ the following corollary emerges.

**Corollary 1 (Output Fluctuations)** *Lower output volatility and higher average output in periods $t_0 + 1, t_0 + 2, ...$ is favored by*
*(i) less inequality of power in period $t_0$,*
*(ii) less mismatch of demand and supply, that is lower (higher) $s$ and higher (lower) $\ell$ if $s > \ell$ ($\ell < s$),*
*(iii) less persistence of power, i.e. lower $\alpha$.*

That is, higher initial inequality in power, wider gap between demand and supply of land, and higher persistence of power in dynasties all tend to accompany more volatile and – on average – lower output. As income inequality is greater under expropriation, this is consistent with evidence on a cross country positive relationship between income equality and macroeconomic stability as measured by the duration of periods with positive growth rates (Berg et al., 2008) and the standard deviation of the rate of output growth (Breen and García-Peñalosa, 2005).

Before concluding let us illustrate the statements in Corollary 1 by providing several examples.

Engerman and Sokoloff (2006) put forward the idea that geographic differences give rise to different institutional shapes when colonial heritage is shared. Former British colonies in the Caribbean were suitable for plantations, which led to greater initial inequality and concentration of land, than

those in the northern parts of America. This was mirrored by the distribution of political power, with plantation respectively farm owners privileged both in terms of social status and their role the political process. Moreover, larger efficient plot size in plantation economies can be viewed in terms of greater mismatch of demand and supply in the land market. The reversal of fortunes of the Caribbean and North America appears thus consistent with our model as initial conditions in the northern economies facilitated stable markets in the long run, though not necessarily in the short run.[15] The existence of a negative association between between inequality of political power and economic outcomes is also supported by the micro evidence provided by Acemoglu et al. (2008a). Using data on political office holding in the state of Cundinamarca, Colombia, they show how concentration of power in the hands of a small group of individual might be detrimental for economic development.

When power in the model is interpreted as wealth, initial wealth inequality is linked to long run macroeconomic performance. Consider therefore the differing postwar growth experiences of Malaysia, South Korea and Philippines mirroring the example provided in Bénabou (1996) and Lucas (1993). The three economies shared similar socio-economic conditions in the 1950s and a similar development of political institutions over the following decades. Initial wealth inequality in Korea was substantially lower than in the other economies, however. Also economic performance differed substantially: Korea experienced higher growth than Malaysia, which in turn outgrew the Philippines. This is mirrored by differences in the extent of expropriation and deficiencies of markets: while assignment appears to be effected by markets in Korea, there is substantial expropriation in the other two economies: via discrimination in education and market access sanctioned by the legal code in Malaysia, and via conflict and corruption in the Philippines, which adds the waste of resources in conflict to allocative distortions.[16]

Concerning the link between persistence of power and sustainability of

[15] Following this line of investigation Henry and Miller (2008) point to the different growth paths experienced after independence by Barbados and Jamaica. Despite a very similar colonial history and geographic conditions, the more equal initial distribution of resources in Barbados (data from Deininger and Squire, 1996) gave rise to more sustained and less volatile levels of economic growth.

[16] This has been noted by Bénabou (1996) comparing Korean and Philippines: although very similar in terms of indices of political rights and civil liberties, market institutions (expropriation risk, corruption, security of property rights, enforceability of contracts etc.) were substantially more evolved in Korea.

markets, Temple and Johnson (1998) report that higher social mobility in an economy is associated to higher subsequent growth. For a more elaborate case consider Japan's transition from feudalism under the Tokugawa shogunate to a market economy in the 19th century (see Beasley, 1972, Jansen, 1995). Exogenous events in form of mounting Western pressure on Japan and China to open up to trade (e.g. the bombardment of Edo in 1853) exposed the allocative cost of expropriation by the warrior class (samurai) and feudal lords (daimyo). In 1868 the emperor's authority was restored (the Meiji restoration), followed by a dramatic institutional change: in 1871 feudal privileges were abolished (samurai lost their stipends and daimyo much of their land holdings), as was the division of the Japanese society into social classes. In 1872 land tenancy was replaced by tradable land titles further eroding the position of the old feudal elite. This was met with opposition (most fiercely during the Satsuma revolution in 1877), but supporters of the new regime prevailed. Interpreted in light of our model this amounts to an exogenous increase in social mobility, facilitating sustainability of markets, as was the case in Japan. China on the contrary avoided social change through concessions to the West, followed by substantial instability.

# 5 Discussion and Conclusion

We presented a tractable framework where economic outcomes are determined by robustness to coalitional deviations of agents. This serves to formalize an abstract institutional constraint on the economic allocation stated on the primitives of the model. This allows focussing on whether adequate institutions implementing markets can be supported without the need of their explicitly modeling. Our results show that unstable markets may be persistent, in the form of limit cycles where markets and expropriation alternate. When persistence of power across generations is sufficiently low, which is best interpreted as high social mobility, markets become sustainable for any initial power distribution, however. Sustainability of markets in economies with low social mobility is favored by less initial power inequality and less mismatch between supply and demand on the land market.

This approach willingly gives up complexity to achieve a modicum of tractability. The results look encouraging, not least since they highlight a number of issues that future research may successfully pursue. We consider only competitive markets; an immediate extension could incorporate other

arrangements, e.g. allowing for non-market-clearing prices or sharecropping. In case of the latter tenants and landlords negotiate sharecropping contracts on a market and the rent distribution sharecropping coincides with the one on a land market. Due to the partnership problem effort is under-provided under sharecropping, so that a market dominates sharecropping. Nevertheless sharecropping may be a stable allocation if the largest consistent set is not a singleton, and our results may generate predictions on its incidence.

Here the transition of power across generations is hardwired into our model. A potential fruitful endeavor left for future research is to capture possible interactions of the economic allocation and the way power is transmitted to future generations, for instance linking persistence of power to technology choice. This may require to analyze stability of markets in a full-blown endogenous growth model. Modeling investment choice allows to explore its interaction with market stability may be and endogenizes the mismatch of demand and supply on the market. This may cause only certain paths of investment behavior to be consistent with sustainable markets.

Finally, future research should consider robustness of market allocations to both expropriation of inputs and outputs of production. To do so markets might open twice in a period. This yields a number of potentially interesting strategic considerations. For instance, desirability of expropriation today will depend on the continuation valuation of land holdings, which in turn will depend on whether markets will be stable tomorrow. Adding uncertainty will enrich the set of contracts usable in a market and may allow to explain the development of a state of anarchy into full Arrow-Debreu markets.

# A Mathematical Appendix

## Example: Emptiness of the core, non-existence of a stable set, and the largest consistent set

In the following numerical example the binary relation $\succ$ is not transitive. This in turn will lead to emptiness of the core and non-existence of a von Neumann-Morgenstern stable set.

### Core and stable sets

Suppose that measure $1/2$ of agents are *weak* having power $\omega_i = 2/3$, while the remaining agents are *strong* with power $\omega_i = 1$. Let agents become skilled with probability $s = 1/3$ independently of land holdings and power.

Suppose $\ell = 1/2$, i.e. land is abundant. The distribution of land is as follows. Measure $\epsilon \in (0, 1/2)$ of weak agents hold land, and so do measure $1/2 - \epsilon$ of strong agents.

A Walrasian allocation ($W$) assigns land to all the skilled and makes unskilled agents indifferent between holding land and not holding land as the measure of land exceeds the measure of skilled. Compare now a Walrasian allocation to an allocation that assigns all land to the most powerful, i.e. to the strong agents, the jungle ($E$). Measure $\epsilon$ of strong agents strictly prefer $E$, while measure $\epsilon + (1/2 - \epsilon)/3$ of weak agents strictly prefer $W$ as they are not expropriated or able to obtain a rent buying land in the market. Hence,

$$W \succ E \Leftrightarrow \frac{2}{3}\epsilon + \frac{2}{3}\left(\frac{1}{2} - \epsilon\right)\frac{1}{3} > \epsilon \Leftrightarrow \epsilon < 1/3.$$

Consider now an allocation that assigns land to all *skilled* strong agents, and to measure $2\epsilon/3 + \gamma$ of *skilled* weak agents, with $\gamma \geq 0$, and to measure $2(1/2 - \epsilon)/3 - \gamma$ of *unskilled* strong agents, but not to *unskilled* weak agents. That is, unskilled weak and measure $\gamma$ of unskilled strong landholders are expropriated. The land is given to the skilled, giving strong agents priority. Call this allocation an expropriation $X(\gamma)$. Clearly, $E \succ X(\gamma)$. Expropriation $X(\gamma)$ in turn dominates the Walrasian allocation if

$$\frac{\epsilon}{3} + \left(\frac{\epsilon}{3} + \gamma\right)\frac{2}{3} > \frac{2\epsilon}{3}\frac{2}{3} + \gamma + \left(\left(\frac{1}{2} - \epsilon\right)\frac{1}{3} - \frac{\epsilon}{3} - \gamma\right)\frac{2}{3}. \tag{9}$$

That is, if $\epsilon + 3\gamma/5 > 1/5$. Suppose for the following that $\epsilon = 1/5$, and therefore (9) holds with equality for $\gamma = 0$. Then

$$W \succ E \succ X(\gamma) \succ W \text{ for } \gamma \in (0, 1/5].$$

None of these allocations are in the core of an appropriately defined cooperative game under nontransferable utility (where a core allocation has to be stable with respect to coalitional deviations, such that deviators are strictly better off and their power exceeds that of strict supporters of the core allocation). Since $E$ dominates all other non-Walrasian allocations as $1 > 2/3$, such a core must be empty.

Likewise a von Neumann-Morgenstern stable set fails to exist. To see this suppose that $E$ is not in a stable set. Then the stable set consists only of Walrasian allocations, because $E$ dominates non-Walrasian allocations. This contradicts external stability as $X(\gamma) \succ W$ for $\gamma > 0$. Suppose therefore that $E$ is in a stable set. Internal stability then requires $E$ to be the only element in the stable set. But this contradicts external stability as $W \succ E$.

**Indirect dominance and the largest consistent set**

Turn now to the indirect dominance relation as defined by Chwe (1994):

> An allocation $a$ is indirectly dominated by allocation $b$ if there exist allocations $a_0, a_1, a_2, ..., a_m$ (where $a_0 = a$ and $a_m = b$) and coalitions $S_0, S_1, S_2, ..., S_{m-1}$ such that $a_i \rightarrow_{S_i} a_{i+1}$ and $a_i \prec_{S_i} b$ for $i = 0, 1, 2, ..., m-1$.

$a_i \rightarrow_{S_i} a_{i+1}$ indicates that coalition $S_i$ can replace $a_i$ by $a_{i+1}$. This corresponds to $S_i$ being a power majority of strict winners when comparing $a_i$ to $a_{i+1}$, i.e. $a_{i+1} \succ a_i$.

Indirect dominance $b \gg a$ via $a_i$ in the sense of Chwe (1994) requires a power majority for both the move from $a$ to $a_i$ and the move from $a_i$ to $b$. At each move a power majority has to strictly prefer the final allocation $b$ to the status quo. But this implies that $b \succ a$, i.e. $b$ directly dominates $a$. Hence, indirect dominance implies direct dominance and an allocation $b$ only indirectly dominates an allocation $a$ via $a_i$ if both $b \succ a$ and $b \succ a_i$.

If in contrast to Chwe (1994) indirect dominance of $b$ over $a$ via $a_i$ only requires that $a_i \succ a$ and $b \not\prec a_i$, indirect dominance becomes meaningful in our setup. In particular, there is an allocation $a$, such that $W \gg a$ via $E$ but $W \not\prec a$. An instance of such an allocation is $X(0)$, as by (9) for $\gamma = 0$ aggregate power of winners and losers from a move to $W$ are equal when $\epsilon = 1/5$. As $E \succ X(0)$ indeed $W \gg X(0)$ via $E$. Moreover, $X(\gamma) \succ X(\gamma')$ whenever $\gamma < \gamma'$, since land is redistributed from measure $\gamma' - \gamma$ of strong agents to weak agents.

Indeed the set $\{W, E, X(0)\}$ is consistent, since any allocation dominating $W$, i.e. $X(\gamma) \prec X(0) \in Y$ (for $\gamma > 0$), any allocation dominating $E$, i.e. $W \ll X(0) \in Y$ via any $X(\gamma)$ (with $\gamma > 0$), and any allocation dominating $X(0)$ is directly dominated by $W \in Y$, but $X(0) \not\prec W$. Moreover, for any admissible $Z \notin Y$, $Z \prec E$. But either $Z \not\succ W$, in which case $E$ cannot be deterred by $W$, or $Z \succ W$ (in which case $E$ can be deterred). Yet as $Z \neq X(0)$ and $Z \succ W$ implies $Z \prec X(0)$, in this last case there is an allocation $X(\gamma)$, $\gamma > 0$, with $X(\gamma) \succ Z$ and $X(\gamma) \succ W$. $X(\gamma)$ cannot be deterred by $E$ or $X(0)$ as $E \succ Z$ and $X(0) \succ Z$. As $Y \subset \bar{Y}$, so are $W$, $E$, and $X(0)$.

## Proof of Proposition 2

The proof proceeds in four steps.

*Step 1.* Since all elements in $W(\lambda^0)$ are payoff equivalent, it suffices to consider a typical element $(\lambda^M, p^M) \in W(\lambda^0)$. Three regimes may emerge.
(i) Let $(\lambda^E, 0) \succ (\lambda^M, p^M)$. Then $\bar{Y} = (\lambda^E, 0)$ as noted in the text.
(ii) Let $(\lambda^M, p^M) \succ (\lambda, 0)$ for all admissible $(\lambda, 0)$. Then $\bar{Y} = W(\lambda^0)$.
(iii) Let $(\lambda^M, p^M) \succ (\lambda^E, 0)$. Suppose there is an admissible $(\lambda, 0)$ such that $(\lambda', 0) \succ (\lambda^M, p^M)$. By Proposition 1 $(\lambda^E, 0) \succ (\lambda', 0)$ and there is a cycle. Denote by $X = \{(\lambda, 0) : (\lambda, 0) \text{ admissible}, (\lambda, 0) \succ (\lambda^M, p^M)\}$ the set of expropriations that dominate the spot market allocation.

*Step 2.* Note that there is always an admissible allocation $(\lambda^X, 0) \nsucc (\lambda^M, p^M)$ such that $(\lambda, 0) \succ (\lambda^X, 0)$ implies $(\lambda^M, p^M) \succ (\lambda, 0)$.

To see this note that $\int_{i \in C(\lambda)} \omega_i di - \int_{j \in C'(\lambda)} \omega_j dj$ is continuous in $(\lambda_i)_{i \in I}$ when $C(\lambda) = \{i \in I : v(\lambda_i^0, \theta_i, \lambda_i, 0) > v(\lambda_i^0, \theta_i, \lambda_i^M, p^M)\}$ and $C'(\lambda) = \{i \in I : v(\lambda_i^0, \theta_i, \lambda_i, 0) < v(\lambda_i^0, \theta_i, \lambda_i^M, p^M)\}$. Therefore the assumption $(\lambda', 0) \succ (\lambda^M, p^M) \succ (\lambda^E, 0)$ implies by the intermediate value theorem that there exists a non-empty set $K$ of admissible allocations such that $\int_{i \in C(\lambda^K)} \omega_i di - \int_{j \in C'(\lambda^K)} \omega_j dj = 0$ for all $(\lambda^K, 0) \in K$.

For any $(\lambda', 0) \in X$ define the measure of landowners' power by $P_L(\lambda) = \int_{i \in I : \lambda_i = 1} \omega_i di$. Note that $P_L(\lambda) > P_L(\lambda')$ implies $(\lambda, 0) \succ (\lambda', 0)$. Define an allocation $(\lambda^X, 0) = \arg\max_{(\lambda, 0) \in K} P_L(\lambda)$. Since $F(\omega)$ is atom-less a revealed preference argument validates that $P_L(\lambda^X) > P_L(\lambda')$ for all $(\lambda', 0) \in X$ since the constraint induced by $(\lambda', 0) \succ (\lambda^M, p^M)$ must be binding as $(\lambda^M, p^M) \succ (\lambda^E, 0)$ (implying there exist some weak agents in all allocations in $X$ that are assigned land) holds.

*Step 3.* We now show that $Y = (\lambda^E, 0) \cup W(\lambda^0) \cup (\lambda^X, 0)$ is consistent. To do so we note that
(a) for all allocations that dominate $(\lambda^E, 0)$ (i.e. $W(\lambda^0)$) the allocation $(\lambda^X, 0) \subset Y$ (in)directly dominates $(\lambda^M, p^M)$ via some $(\lambda', 0) \in X$, but $(\lambda^E, 0) \succ (\lambda, 0)$ for all admissible allocations $(\lambda, 0)$.
(b) For all allocations that dominate $(\lambda^M, p^M)$, that is all $(\lambda', 0) \in X$, there exists $(\lambda^E, 0) \in Y$, with $(\lambda^E, 0) \succcurlyeq (\lambda', 0)$ but $(\lambda^M, p^M) \succ (\lambda^E, 0)$.
(c) For all allocations that dominate $(\lambda^X, 0)$, that is all $(\lambda', 0) \succ (\lambda^X, 0)$, $(\lambda^M, p^M) \succ (\lambda', 0)$, as shown in Step 2 above. But $(\lambda^X, 0) \nsucc (\lambda^M, p^M)$.
(d) For all $(\lambda', 0) \notin Y$ with $(\lambda^M, p^M) \succ (\lambda', 0)$,we have $(\lambda^E, 0) \succ (\lambda', 0)$. This deviation cannot be deterred by a market outcome. For all $(\lambda', 0) \notin Y$ with $(\lambda^M, p^M) \prec (\lambda', 0)$, there is always an allocation $(\lambda'', 0)$ such that $(\lambda'', 0) \succ (\lambda', 0)$ and $(\lambda'', 0) \succ (\lambda^M, p^M)$. Altough $(\lambda'', 0) \prec (\lambda^X, 0)$ and $(\lambda'', 0) \prec (\lambda^E, 0)$, $(\lambda'', 0)$ cannot be deterred by $(\lambda^X, 0)$ or $(\lambda^E, 0)$ since

$(\lambda', 0) \prec (\lambda^X, 0)$ and $(\lambda', 0) \prec (\lambda^E, 0)$. So $(\lambda', 0)$ cannot be in the consistent set.

*Step 4.* Since $Y$ is consistent, whenever $W(\lambda^0) \in Y$, market allocations are in also in the largest consistent set, that is $W(\lambda^0) \subset \bar{Y}$. □

## Proof of Proposition 3

(i) Evident from (4) and (5).
(ii) The proof constructs a power redistribution that decreases the difference RHS - LHS of the relevant condition in (4), (5). Choose $\tau > 0$ and let $\omega'$ denote the power distribution after redistributing. Set $\omega'_i = (1-\tau)\omega_i$ if $\omega_i \geq \hat{\omega}$, and set $\omega'_j$ for $j \in I : \omega_j < \hat{\omega}$ such that $\omega'_j \leq (1-\tau)\hat{\omega}$ and

$$\int_{j \in I : \omega_j < \hat{\omega}} \omega'_j dj = \int_{j \in I : \omega_j < \hat{\omega}} \omega_j dj + \tau \int_{j \in I : \omega_j > \hat{\omega}} \omega_j dj. \tag{10}$$

Since $\mu(j \in I : \omega_j < \hat{\omega}) > 0$ by assumption, there is $\tau$ sufficiently small to satisfy (10). This decreases all agents' power at rate $\tau$ and redistributes the proceeds $\tau$ among the weakest, while preserving agents' position with respect to $\hat{\omega}$. The change in the RHS of (4), (5) is thus

$$\Delta RHS = -\tau \int_{\hat{\omega}}^{\overline{\omega}} \omega dF(\omega, \lambda^0 = 0)$$

that is smaller then zero. The change of the LHS depends on $p$.

Let first $p = p_L$. Then the change in the LHS of (4) is positive, $\Delta LHS > 0$, since $\theta$ is independent of $\omega$ and $\lambda$. Thus $\Delta LHS - \Delta RHS > 0$.

In case $p = p_H$ the change of the LHS of (5) satisfies

$$\Delta LHS \geq -\tau(1-s) \int_{\hat{\omega}}^{\overline{\omega}} \omega dF(\omega, 1).$$

Since $(\lambda^E, 0) \succ (\lambda^M, p^M)$,

$$(1-s) \int_{\hat{\omega}}^{\overline{\omega}} \omega dF(\omega, 1) < \int_{\hat{\omega}}^{\overline{\omega}} \omega dF(\omega, 0),$$

so that $\Delta LHS - \Delta RHS > 0$. Another redistribution of power that can be used is one where $\omega'_i = (1-\tau)\omega_i + T$ and $T = \tau \int_{\underline{\omega}}^{\overline{\omega}} \omega dF(\omega)$. □
(iii) Let $\epsilon > 0$ and set $\rho = 1 - \epsilon$. By definition $\text{var}(P) = \text{var}(L) = \ell(1-\ell)$. Thus $E[PL] = (1-\epsilon)\ell(1-\ell) + \ell^2 = \ell(1-\epsilon(1-\ell))$. Then $P \in \{0;1\}$ and $L \in \{0;1\}$ implies $Prob(P{=}L{=}1) = \ell(1-\epsilon(1-\ell))$. Define $\delta := \ell(1-\ell)\epsilon$.

Now measure $\delta > 0$ of agents have $P = 1$ and $L = 0$, and oppose markets. Hence, the RHS of (4), (5) is

$$0 < \int_{\hat{\omega}}^{\overline{\omega}} \omega_i dF(\omega_i, 0) \leq \delta \overline{\omega}.$$

Likewise, measure $\delta$ of agents (with $P = 0$ and $L = 1$) prefer markets. If $p = p_L$ also agents with $P = 0$ and $L = 0$ prefer markets. The LHS of (4) is

$$\int_{\underline{\omega}}^{\hat{\omega}} \omega_i dF(\omega_i, 1) + s \int_{\underline{\omega}}^{\hat{\omega}} \omega_i dF(\omega_i, 0) \geq \delta \underline{\omega} + s(1 - \ell - \delta)\underline{\omega}.$$

Thus a sufficient condition for (4) is

$$\delta < \frac{s(1-\ell)}{\overline{\omega} - (1-s)\underline{\omega}},$$

which implies the statement when $p = p_L$.

Let now $p = p_H$. Then unskilled agents with $P = 1$ and $L = 1$ prefer markets. The LHS of (4) is thus

$$\int_{\underline{\omega}}^{\hat{\omega}} \omega_i dF(\omega_i, 1) + (1-s) \int_{\hat{\omega}}^{\overline{\omega}} \omega_i^0 dF(\omega_i, 1) \geq \delta \underline{\omega} + (1 - s)(\ell - \delta)\hat{\omega}.$$

A sufficient condition for (5) is therefore

$$\delta < \frac{(1-s)\ell}{\overline{\omega} + (1-s)\hat{\omega} - \underline{\omega}}.$$

Then the statement in the proposition follows for $p = p_H$. □

## Proof of Lemma 1

Note that $v(\lambda_i^0, \theta_i, \lambda_i^M, p^M) < v(\lambda_i^0, \theta_i, \lambda_i', 0)$ if and only if $\lambda_i' = 1$ and $\lambda_i^0 = 0$. $v(\lambda_i^0, \theta_i, \lambda_i^M, p^M) > v(\lambda_i^0, \theta_i, \lambda_i', 0)$ if and only if $\lambda_i' = 0$ and $\lambda_i^0 = 1$, or $\lambda_i' = 0$ and $\lambda_i^0 = 0$ but $p < (\theta_i^2 - 1)/2$, or $\lambda_i' = 1$ and $\lambda_i^0 = 1$ but $p > (\theta_i^2 - 1)/2$. Define accordingly the coalitions of winners and losers

$$\begin{aligned} C &= \{i \in I : \lambda_i' < \lambda_i^0 = 1\} \cup \{i \in I : \lambda_i' = \lambda_i^0 = 0 \wedge p < (\theta_i^2 - 1)/2\} \\ &\quad \cup \{i \in I : \lambda_i' = \lambda_i^0 = 1 \wedge p > (\theta_i^2 - 1)/2\}, \\ C' &= \{i \in I : \lambda' > \lambda_i^0\}. \end{aligned}$$

Markets dominate a coalitional expropriation $(\lambda', 0)$ if and only if

$$\int_{i \in C} \omega_i di \geq \int_{i \in C'} \omega_i di.$$

The optimal coalitional expropriation $\lambda'$ then solves

$$\max_{\lambda':\lambda_i\in\{0;1\}} \left( \int_{i\in C'} \omega_i di - \int_{i\in C} \omega_i di \right) \text{ s.t. } \int_{i\in I} \lambda'_i di = \ell.$$

Agent $i$'s marginal contribution to the objective function $\Delta(i)$ of receiving land $\lambda'_i = 1$ (as opposed to $\lambda'_i = 0$) is

$$\Delta(i) = \begin{cases} 0 & \text{if } i \in C \text{ for } \lambda'_i = 0, \lambda'_i = 1 \\ 0 & \text{if } i \in C' \text{ for } \lambda'_i = 0, \lambda'_i = 1 \\ \omega_i & \text{if } i \in C \text{ for } \lambda' = 0, i \notin C', i \notin C \text{ for } \lambda'_i = 1 \\ \omega_i & \text{if } i \notin C, i \notin C' \text{ for } \lambda' = 0, i \in C' \text{ for } \lambda'_i = 1 \\ 2\omega_i & \text{if } i \in C \text{ for } \lambda' = 0, i \in C' \text{ for } \lambda'_i = 1. \end{cases}$$

All other cases can be excluded. Since the constraint binds with equality for the optimal coalitional expropriation $\lambda'_i = 1$ if $\Delta(i) > \widetilde{\omega}$, with $\widetilde{\omega} : \mu(i \in I : \Delta(i) \geq \widetilde{\omega}) = l \vee \widetilde{\omega} = 0$. Conditioning on scarcity of land the statement in the lemma follows. □

## Proof of Proposition 4

We consider first the case $\ell > s$ and then $\ell < s$.
(i) Let $\ell > s$, then $p = p_L = (\theta_L^2 - 1)/2$ and unskilled agents obtain land with probability $q^L$, and skilled agents with certainty. Using the market stability condition (4), $(\lambda^M, p^M) \succ (\lambda^E, 0)$ holds in $t+1$ if and only if

$$(1-\ell)E_{t+1}(\omega|\omega<\hat{\omega}_{t+1}) > (1-\ell)E_{t+1}(\omega|\lambda=0) - s\int_{\underline{\omega}_{t+1}}^{\hat{\omega}_{t+1}} \omega dF_{t+1}(\omega, 0). \quad (11)$$

A market allocation in $t$ rations land uniformly to the unskilled, so that

$$E_{t+1}(\omega|\lambda = 0) = \alpha E_t(\omega) + \beta \left(1 + \frac{\ell(\theta_L^2 - 1)}{2}\right). \quad (12)$$

Uniform rationing assigns land to a fraction $\ell$ of agents with $\omega_{i,t} \leq \hat{\omega}_t$ in the market in $t$. As agents with $\lambda_{i,t+1} = 0$ had lowest income in $t$ (1 or $(\theta_L^2 + 1)/2$), their ranking in the power distribution is preserved. This together with $F_t(\hat{\omega}_t) = (1-\ell)$ implies that

$$F_{t+1}(\hat{\omega}_{t+1}, 0) \geq (1-\ell)^2. \quad (13)$$

Using (12) and (13) on (11), a sufficient condition for stable markets in $t+1$ given that markets were stable in period $t$ is

$$\alpha E_t(\omega) + \beta\left(1+\ell\frac{\theta_L^2-1}{2}\right) \leq E_{t+1}(\omega|\omega<\hat{\omega}_{t+1}) + s(1-\ell)E_{t+1}(\omega|\omega<\hat{\omega}_{t+1}, \lambda=0).$$

Since land is allocated via a market in period $t$,

$$E_{t+1}(\omega|\omega<\hat{\omega}_{t+1}) \geq \alpha E_t(\omega|\omega<\hat{\omega}_t) + \beta(1+\ell(\theta_L^2-1)/2) \text{ and}$$
$$E_{t+1}(\omega|\omega<\hat{\omega}_{t+1}, \lambda=0) \geq \alpha E_t(\omega|\omega<\hat{\omega}_t) + \beta,$$

since aggregate power of the weak in $t+1$ weakly exceeds aggregate power of the weak in $t$ plus the aggregate income of unskilled agents without land endowment in $t$. This bounds below aggregate income under markets of any set of agents with positive measure. The second inequality follows as 1 is a general lower bound on income. Combining the above expressions yields

$$\alpha E_t(\omega) - \beta s(1-\ell) \leq (1+s(1-\ell))\alpha E_t(\omega|\omega<\hat{\omega}_t). \tag{14}$$

(ii) Suppose now that $\ell < s$, then $p = p_H = (\theta_H^2-1)/2$ and skilled agents obtain land with probability $q^H$, while the unskilled do not obtain land. Rewriting the market stability condition (5), $(\lambda^M, p^M) \succ (\lambda^E, 0)$ holds in $t+1$ if and only if

$$\ell E_{t+1}(\omega|\lambda=1) > \ell E_{t+1}(\omega|\omega>\hat{\omega}_{t+1}) - (1-s)\int_{\hat{\omega}_{t+1}}^{\overline{\omega}_{t+1}} \omega dF_{t+1}(\omega, 1). \tag{15}$$

Because of uniform rationing and independence of skill, and land and power, respectively, the marginal distributions in $t+1$ can be expressed as

$$F_{t+1}(\omega,1) = sq^H\left[F_t\left(\frac{\omega-\beta(p_H+1)}{\alpha},0\right) + F_t\left(\frac{\omega-\beta(2p_H+1)}{\alpha},1\right)\right],$$
$$F_{t+1}(\omega,0) = (1-sq^H)\left[F_t\left(\frac{\omega-\beta}{\alpha},0\right) + F_t\left(\frac{\omega-\beta(p_H+1)}{\alpha},1\right)\right]. \tag{16}$$

Since independent of stability of markets at least a share $\ell$ of last period's strongest agents obtained land, because of (16) these agents are among the strongest $\ell$ agents in $t+1$ as well. Therefore

$$\ell - F_{t+1}(\hat{\omega}_{t+1}, 1) > \ell^2,$$

Hence,

$$\int_{\hat{\omega}_{t+1}}^{\overline{\omega}_{t+1}} \omega dF_{t+1}(\omega,1) > \ell^2 E_{t+1}(\omega|\omega>\hat{\omega}_{t+1}, \lambda=1).$$

Using this on (15) a sufficient condition for stable markets in t+1 is

$$E_{t+1}(\omega|\lambda=1) > E_{t+1}(\omega|\omega>\hat{\omega}_{t+1}) - (1-s)\ell E_{t+1}(\omega|\omega>\hat{\omega}_{t+1}, \lambda=1). \tag{17}$$

By independence of skill, and land and power, due to uniform rationing,

$$E_{t+1}(\omega|\lambda=1) = \alpha E_t(\omega) + \beta\left(\ell\theta_H^2 + (1-\ell)\frac{\theta_H^2+1}{2}\right). \tag{18}$$

Turning to the RHS of (17), as landed agents have highest income

$$E_{t+1}(\omega|\omega > \hat{\omega}_{t+1}) < \alpha E_t(\omega|\omega > \hat{\omega}_t) + \beta \left( \ell\theta_H^2 + (1-\ell)\frac{\theta_H^2+1}{2} \right).$$

Moreover, the landed in $t+$ must have bought or inherited land in $t$:

$$E_{t+1}(\omega|\omega > \hat{\omega}_{t+1}, \lambda = 1) > \alpha E_t(\omega|\omega > \hat{\omega}_t) + \beta \left( \ell(\theta_H^2+1)/2 + (1-\ell) \right).$$

Using these inequalities on (17), markets are stable in $t+1$ if they are stable in $t$ and

$$\alpha E_t(\omega) + \beta(1-s)\ell \left( \ell(\theta_H^2-1)/2 + 1 \right) \geq (1-(1-s)\ell)\alpha E_t(\omega|\omega > \hat{\omega}_t). \quad (19)$$

Noting that $\ell E_t(\omega|\omega > \hat{\omega}_t) + (1-\ell)E_t(\omega|\omega < \hat{\omega}_t) = E_t(\omega)$, (19) can be rewritten as

$$\alpha E_t(\omega) - \beta \frac{(1-s)\ell(\ell p_H + 1)}{1/\ell - (2-s)} \leq \frac{(1-\ell)(1/\ell - (1-s))}{1/\ell - (2-s)} \alpha E_t(\omega|\omega < \hat{\omega}_t), \quad (20)$$

if $(2-s)\ell < 1$. Otherwise (19) is trivially satisfied, but coefficients $\phi_1$, $\phi_2$ of a rearranged condition maintain the comparative static properties.

## Proof of Proposition 5

The proof proceeds similarly to the one of Proposition 4.
(i) Start with the case $s < \ell$, then $p = p_L = (\theta_L^2 - 1)/2$ and the market assigns land to all skilled agents, and to unskilled agents with probability $q^L$. Since aggregate power of all agents without land must weakly exceed aggregate power of weak agents without land, an inclusion argument holds:

$$\int_{\underline{\omega}_{t+1}}^{\hat{\omega}_{t+1}} \omega dF_{t+1}(\omega, 0) \leq (1-\ell)E_{t+1}(\omega|\lambda = 0). \quad (21)$$

Using (12) and (21) on (11), a sufficient condition for expropriation to be the only stable outcome in period $t+1$ is

$$E_{t+1}(\omega|\omega < \hat{\omega}_{t+1}) \leq (1-s)\alpha E_t(\omega) + \beta(1-s)(1+\ell(\theta_L^2-1)/2). \quad (22)$$

By assumption markets were stable in period $t$, so that

$$E_{t+1}(\omega|\omega < \hat{\omega}_{t+1}) \leq \alpha E_t(\omega|\omega < \hat{\omega}_t) + \beta\big(s(\theta_H^2 - (1-\ell)p_L) + (1-s)[\ell\theta_L^2 + 1 - \ell]\big). \quad (23)$$

This is since at most fraction $\ell$ of agents with $\omega_t < \hat{\omega}_t$ have land in $t$, which is obvious if there was expropriation in $t-1$. In a market in $t-1$, a fraction

$1-\ell$ of agents with $\omega_{t-1} < \hat{\omega}_{t-1}$ are not assigned land and have income $p_L + 1$ or 1, which is less or equal to any buyer's income. Combining (22) and (23) yields a sufficient condition for expropriation in equilibrium in $t+1$:

$$\alpha E_t(\omega) - \beta \frac{s\theta_H^2 + (\ell - s)p_L}{1-s} \geq \frac{1}{1-s} \alpha E_t(\omega | \omega < \hat{\omega}_t). \tag{24}$$

(ii) Let now $s > \ell$, then $p = p_H = (\theta_H^2 - 1)/2$ and the market assigns land only to skilled, with probability $q^H$. By an inclusion argument as above

$$\int_{\hat{\omega}_{t+1}}^{\overline{\omega}_{t+1}} \omega dF_{t+1}(\omega, 1) < \int_{\hat{\omega}_{t+1}}^{\overline{\omega}_{t+1}} \omega dF_{t+1}(\omega) = \ell E_{t+1}(\omega | \omega > \hat{\omega}_{t+1}).$$

Hence, a sufficient condition for expropriation to be the only stable outcome in $t+1$ is

$$E_{t+1}(\omega | \lambda = 1) < s E_{t+1}(\omega | \omega > \hat{\omega}_{t+1}). \tag{25}$$

By assumption markets were stable in $t$, so that

$$E_{t+1}(\omega | \omega > \hat{\omega}_{t+1}) > \alpha E_t(\omega | \omega > \hat{\omega}_t) + \beta \left( \ell \frac{\theta_H^2 - 1}{2} + 1) \right),$$

since land buyers have lowest income in $t$. Hence, using (18), a sufficient condition for expropriation as the only stable outcome and thus the equilibrium allocation in $t+1$ (given that market was an equilibrium in $t$) is

$$\frac{\alpha E_t(\omega) + \beta(1 + (1-s)\ell)(\theta_H^2 - 1)/2}{\alpha E_t(\omega | \omega > \hat{\omega}_t)} \leq s. \tag{26}$$

Using that $\ell E_t(\omega | \omega > \hat{\omega}_t) + (1-\ell) E_t(\omega | \omega < \hat{\omega}_t) = E_t(\omega)$ again, this becomes

$$\alpha E_t(\omega) - \beta \frac{1 + (1-s)\ell}{s - \ell} \ell p_H \geq s \frac{1-\ell}{s-\ell} \alpha E_t(\omega | \omega < \hat{\omega}_t).$$

## Proof of Proposition 6

Suppose in a period $t$ a market is stable.

*Part 1.* For the first part suppose a market is stable also in $t+1$, i.e. the appropriate condition of (14) and (19) holds.

(i) Let again first $\ell > s$. Suppose condition (14) holds and markets are indeed stable in period $t$. Then

$$E_{t+1}(\omega) = \alpha E_t(\omega) + \beta(s\theta_H^2 + (\ell - s)\theta_L^2 + (1-\ell)) \text{ and}$$
$$E_{t+1}(\omega | \omega < \hat{\omega}_{t+1}) \geq \alpha E_t(\omega | \omega < \hat{\omega}_t) + \beta(1 + \ell(\theta_L^2 - 1)/2).$$

The second line uses that the landless unskilled have lowest income under markets. Moreover, by (14)

$$(1+s(1-\ell))\alpha E_t(\omega|\omega<\hat{\omega}_t) \geq \alpha E_t(\omega) - \beta s(1-\ell). \tag{27}$$

Applying (14) once more, markets in $t+2$ are stable if

$$\alpha E_{t+1}(\omega) - \beta s(1-\ell) \leq (1+s(1-\ell))(\alpha E_{t+1}(\omega|\omega<\hat{\omega}_{t+1})).$$

This is implied by

$$\begin{aligned}&\alpha E_t(\omega) + \beta(s\theta_H^2 + (\ell-s)\theta_L^2 + (1-\ell)) - \frac{\beta}{\alpha}s(1-\ell)\\ \leq&(1+s(1-\ell))\left[\alpha E_t(\omega|\omega<\hat{\omega}_t) + \beta(1+\ell(\theta_L^2-1)/2)\right],\end{aligned}$$

which, using (27) is implied by

$$1-\ell-\alpha\left[\left(\frac{1}{s}-(1-\ell)\right)\ell p_L + 2p_H\right] \geq 0.$$

(ii) Consider now $\ell < s$. Suppose condition (19) holds and markets are indeed stable in $t$. Then

$$\begin{aligned}&E_{t+1}(\omega) = \alpha E_t(\omega) + \beta(\ell(\theta_H^2-1)+1) \text{ and}\\ &E_{t+1}(\omega|\omega>\hat{\omega}_{t+1}) \leq \alpha E_t(\omega|\omega>\hat{\omega}_t) + \beta(\ell\theta_H^2 + (1-\ell)(\theta_H^2+1)/2).\end{aligned}$$

The second line follows since landholders have highest incomes in markets. Recall (19), which was given by

$$(1-(1-s)\ell)\alpha E_t(\omega|\omega>\hat{\omega}_t) \leq \alpha E_t(\omega) + \beta(1-s)\ell(\ell(\theta_H^2-1)/2+1).$$

Invoking (19) again, a market is stable in $t+2$ if

$$\alpha E_{t+1}(\omega) + \beta(1-s)\ell(\ell(\theta_H^2-1)/2+1) \geq (1-(1-s)\ell)\alpha E_{t+1}(\omega|\omega>\hat{\omega}_{t+1}).$$

This is implied by

$$\begin{aligned}&\alpha E_t(\omega) + \beta(\ell(\theta_H^2-1)+1) + \frac{\beta}{\alpha}(1-s)\ell(\ell(\theta_H^2-1)/2+1)\\ \geq&(1-(1-s)\ell)\left[\alpha E_t(\omega|\omega>\hat{\omega}_t) + \beta(\ell\theta_H^2 + (1-\ell)(\theta_H^2+1)/2)\right],\end{aligned}$$

which, using (19) is implied by

$$\ell(1+\ell p_H) - \alpha\frac{1-2\ell+s\ell}{1-s}p_H \geq 0.$$

*Part 2.* For the second part suppose the appropriate condition of (24) and (26) holds, i.e. expropriation is stable in $t+1$.
(i) Consider $\ell > s$. Let condition (24) hold. Then expropriation is stable in $t+1$, which in turn implies that a market is stable in $t+2$. By (24) expropriation is stable in period $t+3$ again if

$$\alpha E_{t+2}(\omega) - \beta \frac{s\theta_H^2 + (\ell - s)p_L}{1-s} \geq \frac{1}{1-s} \alpha E_{t+2}(\omega | \omega < \hat{\omega}_{t+2}). \tag{28}$$

Stability of expropriation in $t+1$ implies that

$$\begin{aligned} &E_{t+2}(\omega) = \alpha E_{t+1}(\omega) + \beta(\ell[s\theta_H^2 + (1-s)\theta_L^2] + (1-\ell)), \text{ and} \\ &E_{t+2}(\omega | \omega < \hat{\omega}_{t+2}) = \alpha E_{t+1}(\omega < \hat{\omega}_{t+1}) + \beta. \end{aligned}$$

By assumption markets are stable in $t$, which implies as above that

$$\begin{aligned} &E_{t+1}(\omega) = \alpha E_t(\omega) + \beta(s\theta_H^2 + (\ell - s)\theta_L^2 + 1 - \ell) \text{ and} \\ &E_{t+1}(\omega | \omega < \hat{\omega}_{t+1}) \leq \alpha E_t(\omega | \omega < \hat{\omega}_t) + \beta(s(\theta_H^2 - (1-\ell)p_L) + (1-s)(\ell\theta_L^2 + 1 - \ell). \end{aligned}$$

Moreover, by assumption condition (24) holds:

$$\alpha E_t(\omega | \omega < \hat{\omega}_t) \leq (1-s)\alpha E_t(\omega) - \beta(s\theta_H^2 + (\ell - s)p_L).$$

Using these expressions on (28), expropriation is stable in $t+3$ if

$$(1-s)[\ell(s\theta_H^2 + (1-s)\theta_L^2) + (1-\ell)] \geq \frac{\alpha + s\theta^H + (\ell - s)(\theta_L - 1)/2}{\alpha(1+\alpha)}.$$

This condition holds for instance when $\alpha$ is sufficiently large.
(ii) Suppose now $\ell < s$ and that condition (26) holds, so that

$$\alpha E_t(\omega) + \beta(1 + (1-s)\ell)(\theta_H^2 - 1)/2 \leq s\alpha E_t(\omega | \omega > \hat{\omega}_t).$$

Using (18) and (25), expropriation is stable in period $t+3$ if

$$\alpha E_{t+2}(\omega) + \beta \left( \ell\theta_H^2 + (1-\ell)\frac{\theta_H^2 + 1}{2} \right) < sE_{t+3}(\omega | \omega > \hat{\omega}_{t+3}). \tag{29}$$

Note here that the identity of the strong ($\omega_i > \hat{\omega}$) agents does not change over time, i.e. $\omega_{i,t+1} > \hat{\omega}_{t+1}$ implies $\omega_{i,t+j} > \hat{\omega}_{t+j}$, $j = 2, 3$ since all the rent goes to the sellers on a market, see Proposition 7. Therefore

$$E_{t+3}(\omega | \omega > \hat{\omega}_{t+3}) = \alpha E_{t+2}(\omega | \omega > \hat{\omega}_{t+2}) + \beta(\ell\theta_H^2 + (1-\ell)(\theta_H^2 + 1)/2).$$

Expropriation in $t+1$ implies that

$$E_{t+2}(\omega) = \alpha E_{t+1}(\omega) + \beta(\ell[s\theta_H^2 + (1-s)\theta_L^2] + (1-\ell)), \text{ and}$$
$$E_{t+2}(\omega|\omega > \hat{\omega}_{t+2}) = \alpha E_{t+1}(\omega|\omega > \hat{\omega}_{t+1}) + \beta(s\theta_H^2 + (1-s)\theta_L^2).$$

Hence, (29) is equivalent to

$$\alpha^2 E_{t+1}(\omega) + \alpha\beta(1-\ell) + \beta(1-s)(\ell(\theta_H^2 + (1-\ell)(\theta_H^2+1)/2)$$
$$< s\alpha^2 E_{t+1}(\omega|\omega > \hat{\omega}_{t+1}) + \alpha\beta(s-\ell)(s\theta_H^2 + (1-s)\theta_L^2).$$

As above assuming markets are stable in $t$ implies that

$$E_{t+1}(\omega) = \alpha E_t(\omega) + \beta(\ell\theta_H^2 + 1 - \ell) \text{ and}$$
$$E_{t+1}(\omega|\omega > \hat{\omega}_{t+1}) \geq \alpha E_t(\omega|\omega > \hat{\omega}_t) + \beta(\ell(\theta_H^2 - 1)/2 + 1).$$

Using these expressions on (29), a sufficient condition for expropriation in $t+3$ is given by

$$\alpha^2((1-\ell(1-s))p_H + s\ell) + \alpha(s-\ell)\left(s\theta_H^2 + (1-s)\theta_L^2 - \frac{1-\ell}{s-\ell}\right)$$
$$> (1-s)(1+\ell)(p_H+1).$$

This condition holds for $\alpha$ sufficiently great or $s$ sufficiently close to 1. □

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## Supplementary Material: Sharecropping

Short of selling their land, land holders may have the possibility to offer the use of their land to tenants in exchange for a share of the output. This is known as sharecropping, but applies more generally to partnerships. Suppose landlord and tenant agree on a sharing rule $t$ where $t$ is the share of output that goes to the tenant. The tenant's effort choice solves

$$\max_{e_i} t\theta_i e_i - \frac{e_i^2}{2},$$

that is $e_i = t\theta_i$ and output $y = t\theta_i^2$. Individual rationality requires $t^2\theta_i^2/2 > 1/2$ for the tenant, and $(1-t)t\theta_i^2 + 1/2 > \theta_j^2/2$ for the landlord $j$. This already implies $\theta_i > \theta_j$, so that individual rationality is equivalent to

$$t > \frac{1}{\theta_H} \text{ and } s < \frac{1}{2}\left(1 + \sqrt{1 - \frac{\theta_L^2 - 1}{\theta_H^2}}\right).$$

Surplus from this arrangement is $t(1-t/2)\theta_H^2 + 1/2$ which is less than under an exchange of ownership. The same holds for output.

If there is a market for sharecropping contracts the sharing rule $t$ is determined by scarcity. Low skilled agents with land form the supply of landlords and high skilled agents without land are potential tenants forming the demand for sharecropping arrangements. Hence, if $s > \ell$, that is $s(1-\ell) > (1-s)\ell$, landlords are scarce and $t$ must make tenants indifferent between sharecropping and subsistence. If $s < \ell$ landlords are abundant and, in order to equate demand and supply, must be indifferent between sharecropping and working their land on their own. That is,

$$t = \begin{cases} t_H = \frac{1}{2}\left(1 + \sqrt{1 - \frac{\theta_L^2 - 1}{\theta_H^2}}\right) & \text{if } s < \ell \\ t_L = \frac{1}{\theta_H} & \text{if } s > \ell. \end{cases}$$

Corresponding payoffs are $t^2\theta_H^2/2$ for the tenant and $(1-t)t\theta_H^2 + 1/2$ for the landlord. Under markets for land payoffs are $\theta_H^2/2 - p$ for the tenant and $p + 1/2$ for the landlord. Clearly, both landlords and tenant prefer a spot market so that markets dominate sharecropping. This is, however, not sufficient to rule out sharecropping as a stable outcome. Since the sharing of rents (although not their size) is the same under markets and sharecropping, the largest consistent set may contain allocations implied by markets, expropriation, and sharecropping, and as a deterrent, an allocation $(\lambda^*, 0)$ defined in Step 2 of the proof of Proposition 2. Hence, the results in section 3.4 can be used to generate predictions on the incidence of sharecropping.