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Open Access Versus Restricted Access in a General Equilibrium with Mobile Capital

Ronan Congar[1] · **Louis Hotte**[2]

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Abstract

Open Access versus Restricted Access in a General Equilibrium with Mobile Capital We consider an economy with two sectors, resource and manufacturing, in a general-equilibrium setting. Two property regimes in the resource sector are compared, open access versus restricted access, with both labor and capital mobility. We first contribute by deriving the multi-factor demand conditions under open access. We provide necessary and sufficient conditions for a factor to gain from a property regime change. Redistributive effects depend crucially on relative factor intensities. Contrary to common wisdom, labor may gain from being "expelled" from the resource sector following privatization.

Keywords Property rights · Natural resources · Open access · General equilibrium · Mobile capital · Factor payments · Factor intensities · Income distribution

JEL Classification D02 · D23 · D33 · K11 · Q2 · N5 · O13

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✉ Louis Hotte
louis.hotte@uottawa.ca

Ronan Congar
ronan.congar@normandie-univ.fr

[1] Département d'Économie, Université de Rouen Normandie et Normandie Université, Esplanade de la Paix, CS 14032, 14032 Caen Cedex 5, France

[2] Economics Department, University of Ottawa, 120, University Dr., Ottawa, ON K1N 6N5, Canada

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1 Introduction

A central result in the literature on property right economics holds that in a general equilibrium setting, the privatization[1] of the natural resource sector, even though it leads to a more efficient reallocation of labor, will cause wages to decrease. This result is attributed to Weitzman (1974) and Samuelson (1974), who more generally show that restricting access in the use of a fixed factor (e.g. natural resource or agricultural land) makes the variable factor (e.g. labor) worse off as compared to a situation of free access to the fixed factor. We reconsider this question by adding capital as a second mobile factor. This turns out to make a major difference as we obtain that labor wages may actually increase following privatization.

There is an apparent paradox associated with the fact that labor benefits from being effectively expelled from the resource sector following the creation of property rights. To resolve this paradox, imagine an economy with two sectors, manufacturing and (natural) resource. The resource sector is initially exploited under open access. While restricting access to the resource sector may drive out labor, it will also drive out capital. As both factors move into the manufacturing sector in (generally) unequal proportions, factor intensities are affected and consequently, factor returns change in opposite directions. *Our principal result states that labor benefits from resource privatization if, and only if, the manufacturing sector is labor intensive relative to the resource sector.*

The situation is reminiscent of the distinction between the specific-factor and the Heckscher-Ohlin models of trade.[2] The specific-factor model assumes that only labor can move between sectors while capital is riveted to its sector; as such, its implications are viewed as delivering the *short-run*, factor-income effects of trade. Given that the analyses by Weitzman and Samuelson are based on the same assumption, one may similarly view their results as the short-run effects of a property regime change. The Heckscher–Ohlin model takes a longer term view by assuming that both labor and capital can freely move between sectors. By analogy, our results may be viewed as the *long-run*, factor-income effects of a property regime change.

Another main contribution consists in deriving the equilibrium conditions that must prevail under open access in the presence of *two* (or more) mobile factors of production, a fixed factor, and individually rational behavior. This in fact extends the work of Gordon (1954) to an *explicit* consideration of two factors. These equilibrium conditions turn out to be rather intuitive in retrospect; yet, they have escaped the literature so far. We believe that this theoretical contribution will take on practical significance for applied work and policymaking.

We further show that resource privatization causes the price of one mobile factor to decrease and another to increase. Hence, for households that derive income from both labor and capital, the net effect is ambiguous. We show, however, that the net effect leads to an overall decrease in the unit cost of effective input efforts. Both factors will

[1] Throughout the analysis, depending on the context or associated literature, terms like “privatization”, “restricted access” or “regulated access” are used interchangeably to represent a managed resource under a property regime to be defined precisely in Sect. 3. This is in opposition to a situation of an unmanaged resource, where terms like “open access”, “free access” or “uncontrolled access” are used. We refrain from using the expression “common property” as it may or may not represent a managed resource, depending on the literature.

[2] See Jones (1971), Mayer (1974) and Mussa (1974).

nonetheless leave the resource sector, though in unequal proportions, such that the resource is exploited less intensively. And finally, we show that in percent terms, the relative magnitudes of the factor income changes hinges on the ratio of factor cost shares that prevail in the manufacturing sector.

The Weitzman–Samuelson proposition sparked a literature that extended the model's basic assumptions into various directions. Anderson and Hill (1983) argue that privatization may not be more efficient if it leads to competing claims to ownership that use up real resources. Brooks and Heijdra (1990) show that labor wages may increase following privatization if extra labor is required to enforce private property. Brito et al. (1997) consider a heterogeneous labor force and also show that the wage could increase following privatization. Baland and Francois (2005) argue that open access to a resource may act as an insurance mechanism and thus be *ex-ante* Pareto superior to private ownership. Ambec and Hotte (2006) show that when workers have heterogeneous productivities, private property may benefit the less productive when enforcement is imperfect. While all of these papers provide interesting qualifications to the Weitzman–Samuelson proposition, all assume labor to be the only variable factor. Though this may seem a fair assumption to make for the short run, a longer run view should include capital as a second variable factor.

To our knowledge, de Meza and Gould (1987) is the only paper that hints at the potentially important role of a second variable factor in the Weitzman–Samuelson framework. With the help of a fully-specified general-equilibrium model, our analysis allows us to uncover the precise mechanisms at work, find the necessary and sufficient conditions under which wages increase following privatization, and predict the effects of restricted access on the equilibrium prices of *both* labor and capital.

This paper was also inspired by Karp (2005), who argues that when considering the interactions between trade openness, property regimes, and natural resource use, one should treat *both* labor and capital as mobile factors between the resource and manufacturing sectors. This was in response to other analysis that ignored the role of capital, such as Chichilnisky (1994), Brander and Taylor (1997), Hotte, Long and Tian (2000) and Copeland and Taylor (2009). Karp, however, focuses on the different issue of the link between trade openness and the excludability of capital use.

The analysis is of relevance to computable general equilibrium (CGE) modelling of economies in which the resource sector plays an important role. Indeed, the introduction of resource use restrictions is likely to reallocate factors of production in the general economy and therefore affect factor incomes. Manning et al. (2014) argue forcefully that those linkages are important for policy prescriptions. In this respect, as our analysis demonstrates, one should not ignore the role of capital re-allocations along with that of labor. In the case of fisheries, one can indeed find applied models that account for the role of capital, such as Finnoff and Tschirhart (2008, 2011), Abbott and Wilen (2009), Deacon et al. (2011) and Manning et al. (2018). By clarifying the mechanisms at work and identifying the crucial parameters, our theoretical analysis should prove useful to the CGE modeler concerned with the redistributive effects of regulations.

The paper is organised as follows. In Sect. 2, the economy is defined with production technologies and resource endowments. Sectoral equilibrium conditions are laid out in Sect. 3 for the cases of both open access and restricted access. The main results appear in Sect. 4. In Sect. 5, we briefly discuss some evidence on relative factor intensities. Further results regarding the redistributive effects are derived in Sect. 6. The conclusion offers avenues for future research.

2 The Production Technologies

The economy is composed of two sectors: a manufacturing sector (M) and a (natural) resource sector (R).

2.1 The Manufacturing Sector

Manufactures are produced using two types of factors, labor x_l^M and capital x_k^M, with a constant returns to scale technology. The output y^M of the entire manufacturing sector can thus be represented by the following relation:

$$y^M = F^M(\mathbf{x}^M), \tag{1}$$

where $\mathbf{x}^M$ is input vector (x_l^M, x_k^M) and F^M is a function which is twice continuously differentiable, strictly quasi-concave, homogeneous of degree one, increasing in both arguments and such that $F^M(\mathbf{0}) = 0$.

2.2 The Resource Sector

To simplify, the resource sector is composed of one resource site of size Q. We abstract from stock-flow resource dynamics by assuming that Q is fixed.[3] In order to produce resource goods, three input types are required: labor x_l^R, capital x_k^R, and a resource site of size Q. The resource production technology exhibits constant returns to scale in the *three*-input vector (x_l^R, x_k^R, Q). However, because Q is *fixed* by nature, production in the resource sector really exhibits *decreasing* returns to scale with respect to *variable* input vector $\mathbf{x}^R \equiv (x_l^R, x_k^R)$. Given that the size of input Q is fixed throughout, it is dropped from the notation so that the resource output is simply represented as a function of the two variable inputs.

The resource production function is assumed homothetic with respect to $\mathbf{x}^R$, i.e. $y^R = f(F^R(\mathbf{x}^R))$, with function f assumed twice continuously differentiable, increasing, strictly concave and such that $f(0) = 0$, and function F^R is assumed twice continuously differentiable, strictly quasi-concave, homogeneous of degree one, increasing in both arguments and such that $F^R(\mathbf{0}) = 0$. The *effective* effort exerted at exploiting the resource is therefore represented by $z = F^R(\mathbf{x}^R)$. To summarize, we have:[4]

$$y^R = f(z), \quad [\text{ resource output}] \tag{2}$$

$$z = F^R(\mathbf{x}^R). \quad [\text{ effective resource input effort}] \tag{3}$$

[3] The introduction of stock dynamics goes beyond the scope of this paper. It would, however, be straightforward to use our specification and introduce stocks dynamics by assuming period-by-period rent dissipation, as done in Manning et al. (2018) and Squires and Squires and Vestergaard (2013). See Brooks et al. (1999) for a game-theoretic justification of this approach. We leave that for future work.

[4] Finnoff and Tschirhart (2008), Finnoff and Tschirhart (2011) and Deacon et al. (2011) explicitly make use of such a "nested" representation of effective efforts in a CGE model, using a CES technology. Manning et al. (2018) implicitly do the same using a Cobb–Douglas formulation. This in fact only requires the (mild) assumption of homotheticity.

The economy's total endowments in the mobile factors are denoted $\bar{x}_i$, $i \in \{l, k\}$. The following input market clearing conditions must therefore be respected:

$$x_i^M + x_i^R = \bar{x}_i, \quad i \in \{l, k\}. \tag{4}$$

3 Equilibrium Conditions

As mentioned in the previous section, there are three input types in this economy: labor, capital, and a resource site. The first two, labor and capital, are perfectly excludable at no cost. In the case of the resource site, we shall consider two polar cases of property regimes, following Weitzman (1974) and Samuelson (1974):

Restricted Access (RA)	Exclusion is performed by the owner(s) or manager(s) of the resource site, perfectly and costlessly.
Open Access (OA)	The resource site can be accessed by anyone without any restriction whatsoever.

Note that in the case of the RA equilibrium, it is not important to determine who owns the site; all that matters is that owners seek to maximize rents by hiring the right combination of variable inputs, and exclude others. Exclusion can just as well be performed by one firm or by a local community as common property owners.

We take manufactures to be the *numéraire* good. w_i denotes the respective factor prices. p is the price of the resource good. As a simplification, we consider only the case of a small open economy in which p is fixed by world markets. In the case of the endogenous factor prices, we assume price taking behavior by producers throughout and consider only interior solutions in which both sectors are simultaneously active.

3.1 Manufacturing Sector

In order to maximize profits, manufacturers simply equate marginal product values with factor prices, i.e.,[5]

$$F_i^M(\mathbf{x}^M) = w_i, \quad i \in \{l, k\}. \tag{5}$$

In order to represent the equilibrium in the manufacturing sector, it will also be convenient to make use of the cost-minimization dual to (5). Given constant-returns to scale, the unit cost of producing a manufactured good depends on factor prices only and is denoted $c^M(\mathbf{w})$; this function has the usual properties of a cost function. Since manufactures are used as numéraire goods, the equilibrium in the manufacturing sector is represented by the following zero-profit condition:

$$c^M(\mathbf{w}) = 1. \tag{6}$$

[5] The subscript of a function denotes a partial derivative.

3.2 Resource Sector

Equilibrium conditions in the resource sector depend on which property regime prevails.

3.2.1 Restricted Access

Under RA, the resource owner gets to choose variable input vector (x_l^R, x_k^R) by hiring labor and capital in order to maximize profits. The problem of the firm is

$$\max_{\mathbf{x}^R} \pi = pf(z) - \mathbf{x}^R\mathbf{w}', \tag{7}$$

where $z = F^R(\mathbf{x}^R)$ and $\mathbf{w}'$ is the transpose of input price vector $\mathbf{w} \equiv (w_l, w_k)$. This yields the following pair of first-order conditions:

$$pf'(z)F_i^R(\mathbf{x}^R) = w_i, \quad i \in \{k, l\}. \tag{8}$$

This condition simply states that under restricted access, the owner equates the marginal product value of each variable factor to its cost.

When comparing property regimes, it will be useful to look at the problem from the perspective of cost minimization. As a profit maximizer, the owner seeks to minimize the cost of any realized exploitation effort level z. Now given that $z = F^R(\mathbf{x}^R)$, that F^R exhibits constant returns to scale, and price taking, the unit cost of z is considered constant by the resource owner and dependent on input vector cost (w_l, w_k). As a result, letting $c^R(\mathbf{w})$ denote the unit cost of z, the problem of the owner can also be expressed as follows:

$$\max_{z} \pi = pf(z) - zc^R(\mathbf{w}). \tag{9}$$

The owner's optimal exploitation effort is thus given by

$$pf'(z) = c^R(\mathbf{w}). \tag{10}$$

Conditions (8) and (10) are equivalent ways to represent the RA exploitation level on a resource site.

3.2.2 Open Access

In the spirit of Gordon (1954), open access leads to a complete dissipation of rents on a resource site. Looking at it from the perspective of the choice of effective effort level z with unit cost $c^R(\mathbf{w})$, the open-access analog to condition (10) is the following:[6]

$$p\phi(z) = c^R(\mathbf{w}), \tag{11}$$

where $\phi(z) \equiv f(z)/z$ denotes the average product of effective effort.

A remark is warranted here. When comparing expression (10) with (11), one may be inclined to conclude that equilibrium effort z under OA exceeds that of RA because for given z, the average product exceeds the marginal product. That was the essence of

[6] As noted by Cheung (1970), rent dissipation would not be complete under free access with a limited number of users. In this respect, our open access equilibrium approximates a situation with a large number of users. See also Brooks et al. (1999).

Gordon's (1954) argument. But things are not so simple in a general equilibrium setting with mobile factors because a change of property regime will affect factor prices, as noted by Weitzman (1974). The unit cost of effort $c^R(\mathbf{w})$ thus differs between (10) and (11), which means that more analysis is needed in order to determine whether z increases or decreases following resource privatization. A further complication with respect to Weitzman (1974) is that we now have two factors whose prices move in opposite directions, as will be seen below.

In order to arrive at the main result of this paper, we will also need the following proposition, which represents the open-access analog to condition (8):

Proposition 1 *In the presence of two variable inputs, open access is characterized by the following equilibrium conditions, which correspond to rent dissipation:*[7]

$$p\phi(z)F_i^R(\mathbf{x}^R) = w_i, \quad i \in \{k, l\}. \tag{12}$$

Proof Let $x_i(\mathbf{w})$ denote the conditional demand for factor i required to exert one unit of effective effort z. Rent dissipation and cost minimization respectively require: $c^R(\mathbf{w}) = w_k x_k(\mathbf{w}) + w_l x_l(\mathbf{w})$ and $F_k^R/F_l^R = w_k/w_l$. Moreover, since $F^R(\mathbf{x}^R)$ is homogeneous of degree 1, we have $F^R(\mathbf{x}^R) = x_k F_k^R + x_l F_l^R$. With a bit of simple algebra, substitution of the last two equalities into the previous expression for $c^R(\mathbf{w})$ yields $c^R(\mathbf{w}) = w_i/F_i^R$ for $i \in \{k, l\}$. Substitute then into condition (11) to obtain expression (12). □

Conditions (12) can be interpreted as follows. Taking the case of capital to illustrate, adding one more unit of capital will increase the individual effective effort by F_k^R. This increase is then multiplied by the average product of effective effort in order to arrive at the extra output received by *one user*. The fact that it is multiplied by the average product derives from the OA situation; it implies that each user does not account for the negative productivity effects on other users, a negative externality. This contrasts with RA condition (8), where multiplication with the marginal product of effective effort ensures that the drop in productivity of *all users* is well accounted for by the sole resource manager. Before moving on to the results, we wish to formulate the following set of remarks regarding the equilibrium conditions.

1. Conditions (12) subsume two properties of the OA equilibrium: one is a cost minimizing factor combination to achieve effort level z (this is also present in (8) under RA); another is rent dissipation (this differs from RA).
2. Given the well-known inefficiencies associated with an open access regime, the presence of cost minimization may seem odd. But keep in mind that cost minimization applies to the *production* of effort only; the effort *level*, on the other hand, *is* excessive. The OA equilibrium is thus inefficient. Indeed, given that decreasing returns to efforts imply $f'(z) < \phi(z)$, the marginal products of labor and capital are both lower in the resource sector than the manufacturing sector. There is thus excessive use of both labor and capital in the resource sector.[8]

[7] It is straightforward to extend this proposition to any number of inputs or, more generally, to any margin that is left unrestricted.

[8] Note that the excessive use of capital under open access is distinct from the concept of "capital stuffing", as the latter refers to situations of regulated fisheries (Townsend 1985).

3. In deriving conditions (12), we adopted the perspective of firms that hire labor and capital in order to achieve some effective effort level z. The cost minimization assumption is quite natural in this case. But in the case of natural resources, one often envisions individual workers choosing their own capital to work with.[9] Do self-employed workers still minimize the cost of their collective efforts? Somewhat surprisingly, the answer is yes. With Proposition 6 in Sect. 1 of the appendix, we demonstrate that the truly crucial assumption is that workers be free to move between sectors; cost minimization then comes as an unintended consequence.
4. Proposition 6 concerning self-employed workers applies symmetrically to capital owners who hire workers. All that is required is capital mobility between the sectors, effectively making the opportunity cost of capital equal to its return in the manufacturing sector.
5. Regarding the capital mobility assumption, keep in mind that while capital may be "stranded" in the very short run, capital is mobile between sectors in the medium to long run. Indeed, recall that with an annual depreciation rate of 10%, 65% of the capital needs replacement within just ten years.[10] Rational households and investors are unlikely to ignore higher returns in the manufacturing sector for long.
6. While conditions (5) and (12) both correspond to zero profit or rent, the reasons are different. In the case of the manufacturing sector, zero profit derives from the combination of constant returns to labor and capital and price taking. In the case of the resource sector, returns to labor and capital are decreasing; rent dissipation is rather caused by unrestricted access to the fixed factor. Indeed, rents are strictly positive in the resource sector under RA conditions (8).

To recap, under RA, the economy's general equilibrium is characterized by the following set of nine equations: (1), (2), (3), (4), (5) and (8). It contains nine endogenous variables: $\mathbf{w}$, $\mathbf{x}^M, \mathbf{x}^R, z, y^M$ and y^R. In the next section, we will use "hat" superscript $\hat{}$ to denote the equilibrium values of variables under RA.

The general equilibrium under OA is characterized by the following set of nine Eqs. (1), (2), (3), (4), (5) and (12). Compared to RA, only condition (8) has been replaced by (12). We will use "tilde" superscript $\tilde{}$ to denote the equilibrium values of variables under OA.

4 Results

Our main result is presented in Sect. 4.1 in the form of Theorem 1. For expository purposes, in order to demonstrate Theorem 1, we impose *a priori* that the resource sector's effective effort level under RA is lower than under OA, i.e., $\hat{z} < \tilde{z}$. The demonstration that this inequality must hold in equilibrium is deferred until Sect. 4.2.

[9] We are grateful to a referee for raising this point as we believe that its consideration contributes greatly to the analysis.

[10] For the case of fisheries, IREPA (2006) estimates annual depreciation rates of 7% for hulls, 25% for engines and 35% for "other equipment". See also the interesting discussion by Wilen (2009) regarding processing stranded capital arguing that "Most capital involved in fisheries processing is malleable and not likely to be devalued as a result of rationalization".

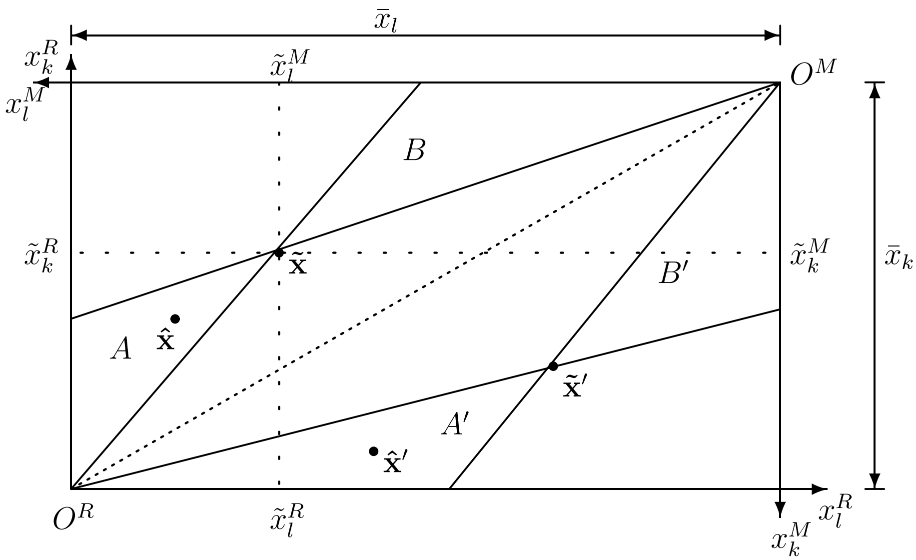

Fig. 1 Property regimes, factor allocations, and factor intensities

4.1 Factor Payment Effects

Let us define factor intensity as follows:

Definition Let $\xi_i(\mathbf{x}^S) \equiv x_i^S/x_j^S$, $i, j \in \{l, k\}$, $i \neq j$, denote factor i's intensity of use in sector S, $S \in \{M, R\}$.

Theorem 1 $\hat{w}_i \geq \tilde{w}_i \Leftrightarrow \xi_i(\tilde{\mathbf{x}}^M) \geq \xi_i(\tilde{\mathbf{x}}^R)$.

Theorem 1 states that restricting access to the resource sector will benefit (harm) the factor that was used more (less) intensively in the manufacturing sector relative to the resource sector under open access. In order to demonstrate this theorem, let us introduce some lemmas.

Lemma 1 states that both sectors' factor intensities vary in the same direction when access is restricted.

Lemma 1 $\xi_i(\tilde{\mathbf{x}}^M) \leq \xi_i(\hat{\mathbf{x}}^M) \Leftrightarrow \xi_i(\tilde{\mathbf{x}}^R) \leq \xi_i(\hat{\mathbf{x}}^R)$.

Proof Regardless of the prevailing property regime, cost minimization in the production of manufactures and resource exploitation effort requires the following condition to hold:

$$\frac{F_i^M}{F_j^M} = \frac{w_i}{w_j} = \frac{F_i^R}{F_j^R}.$$

Now marginal products F_i^M and F_j^M are respectively decreasing and increasing in factor i's intensity. Hence if the factor price ratio w_i/w_j decreases (increases), factor i's intensity must be increasing (decreasing) in both sectors. □

Lemma 1 can be illustrated with the help of Fig. 1. Here, O^R and O^M denote the origins for the resource and manufacturing sectors respectively, and $\bar{x}_l$ and $\bar{x}_k$ are the economy's total factor endowments. One notes that the manufacturing sector is labor (capital) intensive relative to the resource sector for all factor allocations above (below) diagonal line O^RO^M. Lemma 1 therefore implies that if the manufacturing sector is relatively labor (capital) intensive under OA, as with the point labeled $\tilde{\mathbf{x}}$ ($\tilde{\mathbf{x}}'$), then the RA equilibrium must fall in either of areas A or B (A' or B'). One consequence is that the sectors retain their relative factor intensities after the regime change. Hence the following corollary:

Corollary 1 *There is no factor intensity reversal (FIR) associated with a property regime change.*

Proof A reversal of relative factor intensities between sectors implies that equilibria in each property regime are located on opposite sides of the diagonal line O^RO^M in Fig. 1. This violates Lemma 1. □

The following lemma states that when RA is consistent with a drop in effective input efforts as compared to OA, then RA leads to a decreased use of *both* factors in the resource sector. (Note that Lemma 2 does not demonstrate that effective input efforts in the resource sector decrease under RA. This demonstration is deferred to Sect. 4.2.)

Lemma 2 $\hat{z} < \tilde{z} \ \Leftrightarrow\ \hat{\mathbf{x}}^R \ll \tilde{\mathbf{x}}^R$ (*and equivalently* $\hat{\mathbf{x}}^M \gg \tilde{\mathbf{x}}^M$).

Proof (i) $\Rightarrow$ Given that $\hat{z} < \tilde{z}$, then either $\hat{x}_k^R < \tilde{x}_k^R$ or $\hat{x}_l^R < \tilde{x}_l^R$, or both. However, if one factor increases while the other decreases in the resource sector, market clearing implies that the opposite happens in the manufacturing sector, which means that factor intensities move in opposite directions, thus violating Lemma 1. Consequently, it must be the case that $\hat{x}_k^R < \tilde{x}_k^R$ and $\hat{x}_l^R < \tilde{x}_l^R$, and as a result of market clearing, we have $\hat{x}_k^M > \tilde{x}_k^M$ and $\hat{x}_l^M > \tilde{x}_l^M$.

(ii) $\Leftarrow$ is obvious. □

The following lemma states that if, under OA, the manufacturing sector uses factor i more intensively than the resource sector, then the intensity of use of factor i must be lower under RA, and conversely.

Lemma 3 *If* $\hat{z} < \tilde{z}$ *then* $\xi_i(\tilde{\mathbf{x}}^M) \geq \xi_i(\tilde{\mathbf{x}}^R) \Leftrightarrow \xi_i(\tilde{\mathbf{x}}^M) \geq \xi_i(\hat{\mathbf{x}}^M)$.

Proof (i) $\Rightarrow$ According to Lemma 1, given that $\xi_i(\tilde{\mathbf{x}}^M) \geq \xi_i(\tilde{\mathbf{x}}^R)$, as depicted by point $\tilde{\mathbf{x}}$ in Fig. 1, the new equilibrium with RA must fall strictly within either of areas A or B. Lemma 2, however, rules out area B as a possibility when $\hat{z} < \tilde{z}$. As a result, the RA equilibrium is such that $\xi_i(\tilde{\mathbf{x}}^M) \geq \xi_i(\hat{\mathbf{x}}^M)$.

(ii) $\Leftarrow$ (a) Begin with the strict inequality $\xi_i(\tilde{\mathbf{x}}^M) > \xi_i(\hat{\mathbf{x}}^M)$. According to Lemma 1, we also have $\xi_i(\tilde{\mathbf{x}}^R) > \xi_i(\hat{\mathbf{x}}^R)$. It is straightforward to verify then that when $\xi_i(\tilde{\mathbf{x}}^M) < \xi_i(\tilde{\mathbf{x}}^R)$, the preceding two inequalities imply $\hat{z} > \tilde{z}$, which we ruled out.

(b) In the case of a strict equality $\xi_i(\tilde{\mathbf{x}}^M) = \xi_i(\hat{\mathbf{x}}^M)$, Lemma 1 implies $\xi_i(\tilde{\mathbf{x}}^R) = \xi_i(\hat{\mathbf{x}}^R)$. Therefore $F_i^M(\tilde{\mathbf{x}}^M) = F_i^M(\hat{\mathbf{x}}^M)$ and $F_i^R(\tilde{\mathbf{x}}^R) = F_i^R(\hat{\mathbf{x}}^R)$. From (5), (8) and (12) this implies that $pf'(\hat{z}) = p\phi(\tilde{z})$ and thus $\hat{z} < \tilde{z}$. Suppose now that $\xi_i(\tilde{\mathbf{x}}^M) < \xi_i(\tilde{\mathbf{x}}^R)$. It is straightforward to verify then that equal factor intensities under both regimes requires that $\tilde{\mathbf{x}}^R = \hat{\mathbf{x}}^R$ and thus $\hat{z} = \tilde{z}$. A contradiction. □

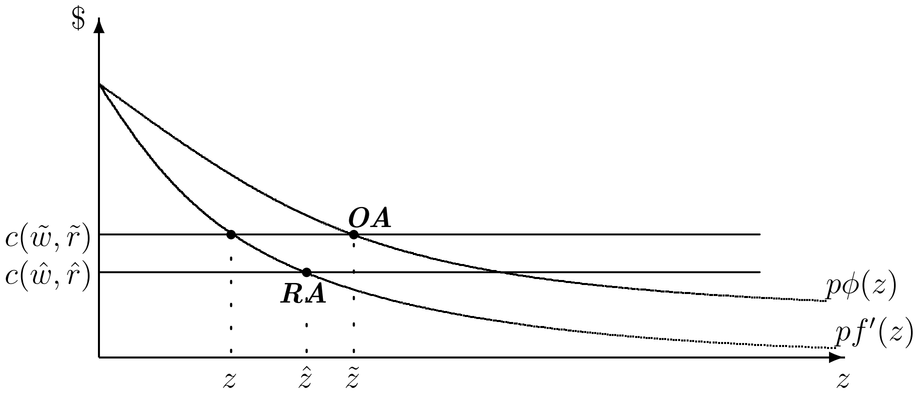

Fig. 2 Resource sector, property regimes, and unit cost of effort

Since a decrease in factor-i intensity can only come about with an increase in the relative cost of factor i, we have the following corollary, which we state without proof:

Corollary 2 *If* $\hat{z} < \tilde{z}$ *then* $\xi_i(\tilde{\mathbf{x}}^M) \geq \xi_i(\tilde{\mathbf{x}}^R) \Leftrightarrow \hat{w}_i/\hat{w}_j \geq \tilde{w}_i/\tilde{w}_j$.

The next lemma states that an increase in the use of factor i's intensity in the manufacturing sector is associated with a lower return to that factor in equilibrium.

Lemma 4 $\xi_i(\tilde{\mathbf{x}}^M) \leq \xi_i(\hat{\mathbf{x}}^M) \Leftrightarrow \tilde{w}_i \geq \hat{w}_i$.

Proof Observe that $\hat{w}_i = F_i^M(\hat{\mathbf{x}}^M)$ and $\tilde{w}_i = F_i^M(\tilde{\mathbf{x}}^M)$. Therefore $\tilde{w}_i \geq \hat{w}_i$ is equivalent to $F_i^M(\tilde{\mathbf{x}}^M) \geq F_i^M(\hat{\mathbf{x}}^M)$. Because marginal product F_i^M is decreasing in factor i's intensity, this is also equivalent to $\xi_i^M(\tilde{\mathbf{x}}^M) \leq \xi_i^M(\hat{\mathbf{x}}^M)$. □

We can now prove Theorem 1.

Proof From Lemma 3, we have $\xi_i(\tilde{\mathbf{x}}^M) \geq \xi_i(\tilde{\mathbf{x}}^R) \Leftrightarrow \xi_i(\tilde{\mathbf{x}}^M) \geq \xi_i(\hat{\mathbf{x}}^M)$. From Lemma 4, the latter inequality is equivalent to $\hat{w}_i \geq \tilde{w}_i$. □

We next turn to the demonstration that the resource effective input effort level must drop when access to the resource is restricted.

4.2 Effective Input Efforts in the Resource Sector

Recall that in order to derive Theorem 1, we have posited that the RA regime's effective effort level in the resource sector would be lower than under OA. This may appear like an obvious consequence of access restriction. However, given that one factor cost is lower under RA than OA, we cannot *a priori* rule out the possibility that the net effect be such that the unit cost of input efforts $c^R(\mathbf{w})$ drops to a level low enough under RA that the resource exploitation level is higher than under OA. In this section, we show first that the unit cost of effective effort in the resource sector is indeed (weakly) lower under RA than OA (see the next Lemma), but that it is still the case that $\hat{z} < \tilde{z}$.

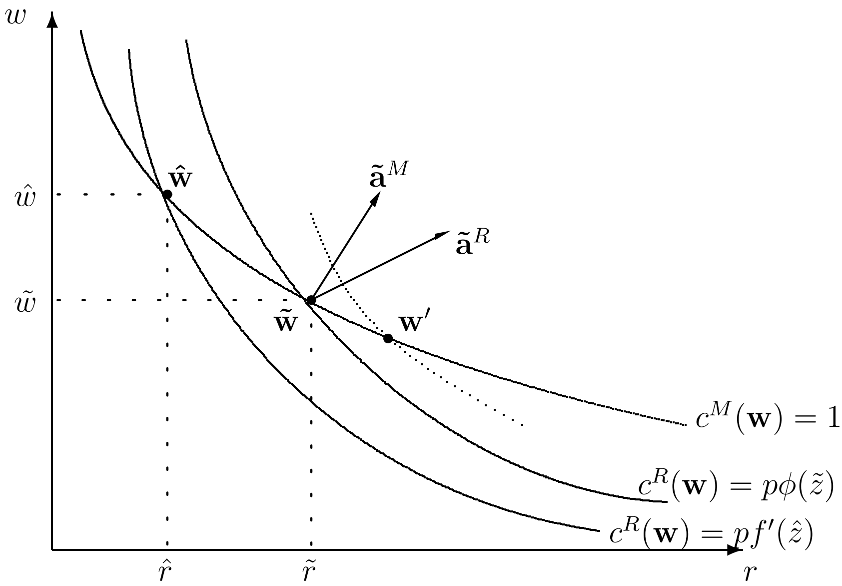

Fig. 3 Isocost curves, property regime equilibria, and factor prices

Proposition 2 $c^R(\hat{\mathbf{w}}) \leq c^R(\tilde{\mathbf{w}})$.

Before demonstrating Proposition 2, let us introduce two figures. Figure 2 represents the resource sector only and identifies the OA equilibrium at the intersection between the unit effort cost $c^R(\tilde{\mathbf{w}})$ and its average product value $p\phi(\tilde{z})$, as per (11).

Making use of the dual approach, equilibrium factor costs can be illustrated on a graph with the use of isocost curves $c^M(\mathbf{w}) = 1$ and $c^R(\mathbf{w}) = p\phi(\tilde{z})$, as in Fig. 3. Indeed, at intersection point $\tilde{\mathbf{w}}$, both sector's equilibrium conditions (6) and (11) are respected and the corresponding factor price vector is the equilibrium one. Note that vectors $\tilde{\mathbf{a}}^M$ and $\tilde{\mathbf{a}}^R$, respectively normal to isocost curves $c^M(\mathbf{w}) = 1$ and $c^R(\mathbf{w}) = p\phi(\tilde{z})$, represent the input vectors per unit of manufactured output and resource effort respectively.[11] Consequently, assuming that the isocost curve of the manufacturing sector crosses that of the resource sector from below, we have that the manufacturing sector is relatively labor intensive at OA equilibrium point $\tilde{\mathbf{w}}$, which corresponds to a point above the diagonal line in Fig. 1, such as $\tilde{\mathbf{x}}$. (The converse holds if the isocost curve of the manufacturing sector crosses from above.) Note that we consider throughout that production is diversified under both property regimes; this requires that the economy's total factor endowment $\bar{\mathbf{x}}$ vector falls within the *diversification cone* formed by the area between vectors $\tilde{\mathbf{a}}^M$ and $\tilde{\mathbf{a}}^R$ and with origin at point $\tilde{\mathbf{w}}$.[12]

[11] This is a consequence of Shephard's lemma which states that $\tilde{\mathbf{a}}^S = (c_i^S(\tilde{\mathbf{w}}), c_j^S(\tilde{\mathbf{w}}))$. See, for instance, chapter 3 of Woodland (1982).

[12] Note also that if the cost functions were to intersect at multiple points, only one would be compatible with any specific total factor endowment.

Proof Proposition 2 is formally demonstrated in Appendix 1. The following argument provides a simple graphical interpretation. Assume instead that $c^R(\hat{\mathbf{w}}) > c^R(\tilde{\mathbf{w}})$. Then according to (11) and (10), we have $pf'(\hat{z}) > p\phi(\tilde{z})$ and thus $\hat{z} < \underline{z} < \tilde{z}$, where $\underline{z}$ is defined as $f'(\underline{z}) = \phi(\tilde{z})$ (see Fig. 2). If the manufacturing sector is relatively labor intensive in the OA equilibrium, curve $c^M(\mathbf{w}) = 1$ intersects curve $c^R(\mathbf{w}) = p\phi(\tilde{z})$ from below (see Fig. 3). Now with $c^R(\hat{\mathbf{w}}) > c^R(\tilde{\mathbf{w}})$, the resource sector's unit effort isocost curve under RA must be above that under OA; this is illustrated by the dotted curve in Fig. 3. The new equilibrium at point $\mathbf{w}'$ is characterized by a drop in the relative price of labor and thus a higher intensity in the use of labor in both sectors. As a consequence, the RA equilibrium falls in region B of Fig. 1, which corresponds to an increased use of both factors in the resource sector and therefore $\hat{z} > \tilde{z}$. A contradiction. □

Proposition 2 implies that the resource sector's RA regime isocost curve lies below that of the OA regime's. Consequently, the RA equilibrium wage vector $\hat{\mathbf{w}}$ must be located above the OA one $\tilde{\mathbf{w}}$ along the manufacturing sector's isocost curve, which is consistent with Theorem 1, i.e., in the case where the manufacturing sector is labor intensive under OA, labor (capital) is more (less) costly under RA than OA. It also implies the following:

Lemma 5 $\hat{z} < \tilde{z}$.

Proof A formal proof is provided in Appendix 1. Graphically, it can be readily verified from Fig. 1 that since the relative cost of labor increases under RA, a lower intensity of its use in both sectors requires that the RA equilibrium factor allocation fall into area A, which is characterized by $\hat{\mathbf{x}} \ll \tilde{\mathbf{x}}$ and therefore $\hat{z} < \tilde{z}$. □

5 Some Evidence on Relative Factor Intensities

The fact that labor may gain from being denied the rents from the natural capital seems like a striking proposition. While the mechanism is now clear, the fact that it requires the manufacturing sector to be labor intensive relative to the natural resource one implies that it would still remain a purely theoretical exercise if this condition were never fulfilled in the real world. While a full empirical investigation goes beyond the scope of this paper, we argue below that it is indeed more than a mere theoretical possibility.

Note first that in the macro-economic literature, for economies taken as a whole, it is customary to assign cost shares of 1/3 and 2/3 for capital and labor respectively, based on the evidence as a first approximation across time and places (Caselli 2005; Weil 2013). Using the typical Cobb–Douglas representation of an economy's GDP, we thus have $Y = AL^{\theta}K^{1-\theta}$, where $\theta = .66$, L represents effective labor input, A is TFP, and K is the aggregate capital stock. If factor wages receive their marginal product, elasticities θ and $1-\theta$ also correspond to the cost shares of labor and capital respectively. Let us therefore use these values as benchmarks.

We begin with two fishery examples. In the case of the albacore fishing fleet in the North Pacific, Squires and Vestergaard (2013) obtain average capital cost shares of 0.4623 and 0.3760 for the U.S. and Canada respectively. Considering that the remaining costs include fuel, oil, gear and labor, this suggests that the labor share must be significantly lower than 2/3 in this fishery. Consequently, other activities in Canada and the U.S. are likely to be more labor-intensive on average compared to this fishery.

One might be inclined to think that while northern fisheries are relatively capital intensive, this may not extend to southern fisheries. This is not necessarily the case. Indeed, for the case of an artisanal fishery located in a poor community in Northern Honduras, Manning et al. (2018) have calibrated the following fishing output function: $y_{fish} = A_{fish} L_{family}^{.174} L_{hired}^{.104} K^{.322} x^{.4}$, where x denotes the resource stock size. Now in line with expressions (2) and (3), this implies $y_{fish} = A' z^{0.6}$ where $A' = A_{fish} x^{.4}$ and $z = L^{.46} K^{.54}$, where L combines both types of labor inputs used on the fishery. With an exponent of just .46 for labor inputs, labor intensity in this artisanal fishery is also likely to be lower than in the rest of the economy.

Turning to petroleum now, its extraction is well-known to be very capital intensive. It has also, at times, been subject to a common pool exploitation which in all respects amounts to an open access use. Daintith (2010) offers fascinating accounts regarding Galicia, Romania and Russia in the late nineteenth century, where parallels are made with cases in the United States during the same period. One way or another, all report on the presence of chaotic races to extract. Later in the mid-twentieth century, common-pool oil extraction remained a major problem in the US (Libecap and Wiggins 1984). In all cases, the presence of wasteful "forests of derricks" suggests the mobilization of larger amounts of capital in proportion to labor as compared to the rest of the economy.[13]

In the case of agriculture, where land is the fixed factor, keep in mind that produced capital includes livestock and treestock (System of National Accounts 2008). Mundlak, Butzer and Larson (2012) correspondingly provide agricultural technology estimates using a panel of 30 developed and developing economies that account for capital of agricultural origin (livestock and treestock), as well as the usual structures and equipment. They obtain that "The sum of the [output] elasticities of the two types of capital is 0.46, and the elasticity of land is 0.44. With the sum of the elasticities of 0.90 for capital and land, there is little scope left for labor and fertilizer" (143). This suggests that, on average, agriculture is much more capital intensive that the rest of the economy.[14] One would assume that this is especially true for pastoral land, which is often subject to an open access use regime. The shift in agricultural production observed in England after the Black Death (1348–1350) provides an interesting historical example. It is argued that as the plague wiped out close to half of the population, the relative cost of labor increased in such a way that a good share of land use shifted from arable to (sheep) pasture, the later being much more capital-intensive, and the transition spread-out over many years in part because of the time needed to build up the livestock (Campbell, Bartley and Power 1996). We are therefore led to presume that in its early stages at least—i.e., before industrialization—enclosure of the open fields may not have had the wage depressing effect envisioned by Cohen and Weitzman (1975).

The above provide examples of three natural resource types that use a relatively capital-intensive technology even under an open access regime. Of course, one could also find other types of natural resources where the technology is rather labor-intensive; artisanal mining comes to mind. Others yet might be more-or-less on par with the rest of the economy. The upshot is that whether the transition to a restricted access regime increases,

[13] Even in 2017 Dean (2017), the New York Times reports on a surprisingly similar situation in Myanmar.

[14] Note that the use of factor income shares as estimators for the parameters of the Cobb–Douglas production function requires that all input uses respect the first-order conditions for profit maximization. This is an unrealistic assumption to make for most developing countries as the land and labor markets are often non-competitive. We understand that it is for this reason that Mundlak, Butzer and Larson (2012) chose to concentrate the discussion on elasticities.

decreases, or leaves wages essentially unchanged is context dependent and consequently, so is its effect on income distribution. One cannot make a one-size-fits-all prediction. As argued by Sokoloff and Engerman (2000), this may have longer-term consequences for an economy given "...the possibility that initial conditions, or factor endowments broadly conceived, could have had profound and enduring impacts on long-run paths of institutional and economic development in the New World." (220)

6 Additional Results Regarding the Redistributive Effects of Privatization

6.1 "Is the Rent-Collector Worthy of His Full Hire?"

Samuelson (1974) shows that the answer to the above question is "no" by arguing that the rents being created from privatization exceed the efficiency gains. His analysis, however, relies on the fact that labor wages decrease following privatization *and* that labor is the only variable factor. Under such a scenario, it is easy to conceive that the newly created rents exceed the increase in GDP. The extension to the two-variable-factor case is not so straightforward because factor payments move in opposite directions, as we have shown.[15] We show in this section that the answer to Samuelson's question is still "no". All that is required is that the cost of effective effort drops, which we have shown to be the case in Proposition 2.

One way to approach the question is through the GDP identity based on the sum of aggregate revenues:

$$Y \equiv \mathbf{w}\bar{\mathbf{x}} + \pi, \tag{13}$$

where π denotes the total rents generated in the resource sector as per (7) and $\mathbf{w}\bar{\mathbf{x}}$ are the aggegate variable factor incomes. Efficiency gains from privatization are thus given by

$$\Delta Y \equiv \hat{Y} - \tilde{Y} = \Delta \mathbf{w}\bar{\mathbf{x}} + \Delta \pi. \tag{14}$$

We therefore have that $\Delta \pi \geq \Delta Y$ if, and only if, $\Delta \mathbf{w}\bar{\mathbf{x}} \leq 0$.

Proposition 3 *The creation of rents in the resource sector following privatization exceeds the efficiency gains and, equivalently, aggregate variable factor incomes decrease.*

Proof It suffices to show that aggregate variable factor incomes decrease following privatization. Our proof is based on the demonstration that, at the margin, these incomes decrease if, and only if, the unit costs of effective efforts decrease.

Let W denote the aggregate variable factor incomes, i.e., $W \equiv \mathbf{w}\bar{\mathbf{x}}$. Given zero profit in the manufacturing sector, we have $W = c^R(\mathbf{w})z + y^M$. Total differentiation implies

$$dW = c^R(\mathbf{w})dz + zdc^R(\mathbf{w}) + dy^M. \tag{15}$$

Since $dz = F^R_l dx^R_l + F^R_k dx^R_k$, we have $c^R(\mathbf{w})dz = c^R(\mathbf{w})[F^R_l dx^R_l + F^R_k dx^R_k]$. But with cost minimization, we have shown that $w_l = c^R(\mathbf{w})F^R_l$ and $w_k = c^R(\mathbf{w})F^R_k$, regardless of the property

[15] We are grateful to the Editor for raising this point.

regime. Substituting into the previous, we obtain $c^R(\mathbf{w})dz = w_l dx_l^R + w_k dx_k^R$. Similarly, in the manufacturing sector, we have $dy^M = w_l dx_l^M + w_k dx_k^M$. Moreover, given the factor endowment constraints in the general equilibrium, we have $dx_l^R = -dx_l^M$ and $dx_k^R = -dx_k^M$. Substituting these into the previous two expressions yields $c^R(\mathbf{w})dz = -dy^M$. Substituting into (15) reduces to, in equilibrium:

$$dW = zdc^R(\mathbf{w}). \tag{16}$$

We consequently have that, at the margin, W decreases if, and only if, $c^R(\mathbf{w})$ decreases. Assuming continuity, the desired result follows from Proposition 2. □

There is an interesting implication here when one compares this result with the analysis by Weitzman (1974). The fact that aggregate variable factor incomes drop after privatization can be conceived, on the one hand, as *consistent* with his result that labor wages drop in the one variable case. But on the other hand, it can conceived as *inconsistent* with his (self-described) main result which states that "The variable factor will always be better off with (inefficient) free access rights than under (efficient) private ownership property." (225) Indeed, Cohen and Weitzman (1975) use this result to argue that "when village land is enclosed [...] the standard of living of the working population declines." (316) We have shown that this is not necessarily the case in the presence of a second variable factor.

It should also be noted that our analysis was conducted in a static setting in order to draw direct comparisons with Weitzman (1974) and Samuelson (1974). In a dynamic setting, for some resource types, large enough resource stock recoveries after privatization may increase total factor productivity by enough to raise all factor incomes. A similar possibility would arise with technological progress. We believe, however, that our results remain relevant in terms of the distribution of those income gains, and therefore under what conditions privatization exacerbates or mitigates inequalities.

6.2 On the Relative Magnitudes of Factor Cost Variations

So far, our analysis has concentrated on the *direction* of changes in factor and effort costs. When discussing the redistributive effects of institutional change, it is also of interest to look at the *relative magnitudes* of these effects. We begin by a look at the percent change in the cost of effective efforts and then turn to a comparison of factor incomes.

Let the dot suffix $(\dot{\ })$ denote the percent change of a variable, i.e., $\dot{u} \equiv du/u$. We have the following proposition:

Proposition 4 *Suppose that the resource sector is relatively intensive in factor i, then the percent drop in the unit cost of factor i exceeds the percent drop in the unit cost of effective efforts in the resource sector, i.e.,*

$$|\dot{w}_i| \geq |\dot{c}^R| \quad \text{if} \quad \xi_i^R \geq \xi_i^M, \quad i \in \{l, k\}. \tag{17}$$

Proof Let θ_i^S denote the cost share of factor i in sector S, i.e., $\theta_i^S = w_i a_i^S / c^S(\mathbf{w})$, where a_i^S is the cost minimizing use of factor i per unit of output (when $S = M$) or effective effort (when $S = R$). The cost function has the following property (see, for instance, Woodland 1982, p. 87):

$$\dot{c}^S = \theta_i^S \dot{w}_i + \theta_j^S \dot{w}_j,\ i \neq j,\ S \in \{M, R\}. \tag{18}$$

We have shown in Theorem 1 and Proposition 2 that with $\xi_i^R \geq \xi_i^M$, both c^R and w_i decrease with resource privatization, while w_j increases. The result follows from the fact that $\theta_h^S \in (0, 1)\ \forall\ h \in \{l, k\}$. □

Suppose, for instance, that the manufacturing sector is relatively labor intensive. Proposition 4 states that the drop in the unit cost of capital will be larger than the drop in the unit cost of effective efforts in the resource sector. Note, however, that nothing so definite can be said about the percent increase in labor wages in comparison to the percent drop in the cost of effective efforts. We can, however, say something about the percent changes in factor incomes, as per the following proposition:

Proposition 5 *In absolute terms, the percent change in factor i exceeds the percent change in factor j if, and only if, the cost share of factor i is smaller than the cost share of factor j in the manufacturing sector, i.e.,*

$$\dot{w}_i \geq -\dot{w}_j \text{ iff } \theta_i^M \leq \theta_j^M. \tag{19}$$

Proof Given that $c^M(\mathbf{w}) = 1$ regardless of property regime, we have $\dot{c}^M = 0$. Substituting into expression (18) for the case of $S = M$ and rearranging, we have:

$$-\frac{\dot{w}_i}{\dot{w}_j} = \frac{\theta_j^M}{\theta_i^M}. \tag{20}$$

□

It is interesting to note that while the result of Theorem 1 is based on a comparison of factor intensities between the two sectors of an economy, Proposition 5 is rather based on the ratio of factor cost shares within the manufacturing sector. This introduces a role for cost shares in the manufacturing sector that is complementary to that of relative factor intensities. Take, for instance, the following scenario.

Suppose that the manufacturing sector is relatively labor intensive in both countries A and B; resource privatization will thus tend to favor labor wages and harm capital returns in both countries. Suppose further that the manufacturing sector's cost share of labor is larger in country A than B; expression (20) tells us that in percent terms, the redistributive effect will tend to be more pronounced in country A than B.

So what do cost shares in the manufacturing sector look like in real life? While a detailed answer to that question goes beyond the scope of our theoretical analysis, the following numbers taken from Gollin (2002) are insightful. In line with the discussion in Sect. 5 above, Gollin makes the point that labor income shares quite consistently represent between 65 and 80% of the total national income across time and places. While this paints a picture of income share homogeneity between countries, things look quite different at the sectoral level. Indeed, according to Gollin (2002 p. 466), "Clearly, even within sectors, there are important differences across countries in employee compensation shares. For example, employee compensation shares in the manufacturing sector range from .749 in Finland to .132 in Ecuador." This indicates how the redistributive effects of resource privatization will vary across time and places not just in terms of who gains and who loses, but also in terms of magnitudes.

Table 1 An illustration

	x_l^R	x_l^M	x_k^R	x_k^M	z	Y^R	Y^M	Y	w_l	w_k	c^R	π^R	MP_K^R
OA	28.6	71.4	38.6	61.4	32.9	32.6	67.7	100.3	.617	.386	.989	0	.232
RASR	16.1	83.9	38.6	61.4	23.8	26.8	75.3	102.0	.583	.429[a]	1.09[a]	0.9a	.174
Δ%[b]	−44	+17	0	0	−28	−18	+11	+1.7	−5.5	+11	+10	–	−25
RALR	7.9	92.1	11.6	88.4	9.5	15.4	90.8	106.2	.641	.359	.978	6.2	.359
Δ%[b]	−72	+29	−70	+44	−71	−53	+34	+5.9	+3.9	−7	−1.1	–	+55

[a] These value are calculated using the cost of capital in the manufacturing sector

[b] Δ% denotes percent changes with respect to the open access equilibrium for both the short and the long run

6.3 An Illustration

So far, we have uncovered the factors that determine the sign of the variations in input prices and the factors that affect the relative magnitudes of these variations. This clarifies the mechanics that link institutional change with technology in its effects on factor incomes. The next question is whether these variations are large in absolute terms. Since the answer to that question must be context dependent, a complete analysis extends beyond the scope of this paper. But for the sake of completeness, we propose the following illustrative experiment based on previously used functional forms and parameter values.

Represent the manufacturing sector's output by the following Cobb–Douglas function:

$$y^M = A^M (x_l^M)^\alpha (x_k^M)^{1-\alpha},\ \alpha = 0.65,\ A^M = 1, \tag{21}$$

where the value for α corresponds to the cost share of labor often used by macro-economists for the aggregate economy (Gollin 2002; Caselli 2005; Weil 2013) and that of productivity level A^M has been normalized to unity.

Assume to simplify that the resource sector is entirely composed of a fishery. Borrowing from Deacon et al. (2011), the effective effort CRS function is represented by the following CES technology, with parameter values taken from one of their simulated middle cases (p. 375):[16]

$$z = \left(\delta\left(x_l^R\right)^\theta + (1-\delta)\left(x_k^R\right)^\theta\right)^{\frac{1}{\theta}}, \quad \delta = 0.522, \quad \theta = -0.279. \tag{22}$$

The total harvesting output is represented by the following decreasing returns Cobb–Douglas form:

$$y^R = A^R z^\beta, \quad \beta = 0.6, \quad A^R = 4, \tag{23}$$

where the value for parameter β is taken from Manning et al. (2018) and that of parameter A^R has been chosen in order to ensure that both sectors be simultaneously active while making the resource sector somewhat smaller than the manufacturing sector. Note that A^R

[16] The value for θ corresponds to an elasticity of substitution of .782.

is a productivity parameter that encompasses both the technological level and the state of the resource stock.

We set factor endowments to $\bar{x}_l = \bar{x}_k = 100$ and the resource price to $p = 1$. The equilibria are reported in Table 1 for three different regimes: open access (OA); restricted access in the short run (RASR); and restricted access in the long run (RALR). In the short run, capital is assumed fixed at the initial open access level but labor is perfectly mobile between the sectors, thus corresponding to the cases of Weitzman (1974) and Samuelson (1974) in which resource managers maximize with respect to labor only. In the long run, the resource manager maximizes with respect to both factors.

We first note that the long run values under restricted access are consistent with the fact that initially, i.e., under open access, the manufacturing sector being more labor intensive than the resource sector, wages increase and capital returns decrease following privatization. The magnitudes are +3.9% for wages and −7% for capital returns. While these numbers may appear moderate, they look rather substantial when compared to the short run values. Indeed, in the short run, wages decrease by 5.5% while capital returns increase by 11%. (Note that in the short run case, w_k denotes the capital returns in the manufacturing sector only, which equals its marginal return there.) The variations between the short and the long run predictions are thus +10% and −16% for wages and capital returns respectively.

Consistently with our predictions, the unit cost of effective efforts drops over the long run, though only by −1.1%. Now with fixed capital, the unit cost function is not meaningful in the short run as it does not factor in the true cost of capital. We nonetheless report on the "implied" cost by making use of the *opportunity cost* of capital, w_k, as it corresponds to its marginal product in the manufacturing sector. This way, we obtain a short-run increase of 10% on the unit cost of effective efforts, resulting in a drop of nearly 11% afterwards.

It is also insightful to report on the evolution of the marginal product of capital in the resource sector, denoted MP_K^R. Under open access, this product (.232) is 40% below that of the manufacturing sector (.386); this is consistent with excessive capital use. Now under restricted access in the short run, as labor moves out to the manufacturing sector while capital is fixed, this discrepancy widens to 60% below (.174 against .429). Such a discrepancy cannot last for a well managed resource. For some time, depreciated resource capital will be mostly rebuilt into the manufacturing sector until the marginal returns are equalized at .359. Consistently with this account, once we factor in the true opportunity cost of capital, we note a significant discrepancy between the resource rents created in the short run (0.9) versus the long run (6.2).

7 Conclusion

The foregoing analysis introduces a qualification to the well-known proposition that privatization in the resource sector causes a drop in wages. Indeed, we have shown that wages will rather increase if the manufacturing sector is relatively labor intensive. This leads to the apparent paradox that workers may actually benefit from being forced out of the resource sector after the creation of property rights. But this can be explained by the fact that capital will follow workers and, through its reallocation to a sector that is more intensive in labor, will contribute to raise wages.

If the manufacturing sector turns out to be capital intensive instead, then workers do lose out from resource privatisation. Now given that factor intensities may vary across time and places, we conclude that one should be wary of making one-size-fits-all predictions regarding the welfare effect of resource or rural privatization on labor.

We have also shown that the returns to capital move in opposite direction to labor wages. Consequently, the effect of a property regime change on factor returns in general depends importantly on relative factor intensities. In any case, following the creation of property rights, both factors will move out of the resource sector, though in varying proportions.

Those structural changes brought about by a property regime change were analyzed with the use of an insightful dual approach that incorporated the role of capital movements. Our analysis focused on factor-income changes and has obvious political-economic implications. But the economic forces that we identify can certainly be used to gain new insights into the links between institutions and factor misallocations, factor migrations, factor intensities, capital deepening and productivity gaps between the resource or agricultural sector and the manufacturing sector. Another promising avenue of research would consist in introducing an explicit consideration of resource stock dynamics. This is left for future work.

Appendix A: Self-employment and Cost-Minimization Under an Open-Access Regime

In this section, we show that cost minimization occurs under open access with self-employed users/workers, as long as they are free to move between the sectors.

Let n denote the total number of workers exploiting the resource. (We keep this number fixed for now. It will be made endogenous below.) $z_j = F^R(x^R_{lj}, x^R_{kj})$ denotes the effective effort expended on the resource by worker j, $j \in \{1, 2, \dots, n\}$. The total effort expended on the resource is thus given by $z = \sum_{j=1}^{n} z_j$, which yields total output $f(z)$ and average product of effort $\phi(z)$. Suppose, to simplify, that a worker inelastically supplies one unit of labor and that she cannot split her time between the manufacturing and the resource sector. We have $x^R_{lj} = 1$, $\forall j$, and individual effort is thus uniquely determined by a worker's choice of capital input x^R_{kj} at cost w_k. We now turn to this choice.

Worker j's net payoff from the resource is given by

$$\pi_j = p\phi(z)z_j - w_k x^R_{kj}, \tag{24}$$

where $z_j = F^R(1, x^R_{kj})$. Now if n is large enough—as must be the case under open access over a large resource site—each resource worker will take $\phi(z)$ as given when deciding on her individual effort level.[17] The first-order condition for j's choice of capital is thus:

$$\frac{\partial \pi_i}{\partial x^R_{kj}} = p\phi(z)F^R_k\left(1, x^{R*}_{kj}\right) - w_k = 0, \ \forall j. \tag{25}$$

This condition has the same interpretation as the one provided above for conditions (12). Now with constant returns to scale, we have $F^R_k\left(1, x^{R*}_{kj}\right) = F^R_k\left(n, x^{R*}_k\right)$, where $x^{R*}_k = n x^{R*}_{kj}$.

[17] See Cheung (1970), Dasgupta and Heal (1979, chap. 3) and Brooks et al. (1999). Note that taking the average product as given is required for total rent dissipation; they go hand in hand.

Consequently, for a given number of workers, the equilibrium total amount of capital hired on the resource site is given by:

$$p\phi(z)F_k^R\left(n, x_k^{R*}\right) = w_k. \tag{26}$$

For the case of capital, we therefore have the same condition as in (12). Given n, this condition determines the equilibrium total and individual efforts being supplied, respectively z^* and z^*/n, along with the corresponding equilibrium individual net payoff $\pi^* = (p\phi(z^*)z^* - w_k x_k^{R*})/n$. Let us now turn to the determination of n.

Given that workers are free to move between the sectors, the equilibrium allocation of workers between manufacturing employment and resource exploitation must be such that they are indifferent between them. This requires that $\pi^* = w_l$. Given that the prevailing wage w_l in the manufacturing sector must be regarded as the true opportunity cost of workers exploiting the resource, this last condition implies total rent dissipation, i.e., $p\phi(z^*)z^* = w_l n + w_k x_k^{R*}$. This leads to the following proposition:

Proposition 6 *With self-employed resource users who are free to move between the sectors, the open-access equilibrium is equivalently characterized by conditions* (12).

Proof The case with $i = k$ has already been derived as condition (26) above. We now derive the case for $i = l$. Because $F^R(\mathbf{x}^R)$ has constant returns to scale, we have $z = x_l^R F_l^R + x_k^R F_k^R$. Substituting (26), this gives $z = x_l^R F_l^R + w_k x_k^R / p\phi(z)$ or, equivalently, $p\phi(z)z = p\phi(z)x_l^R F_l^R + w_k x_k^R$. Making use of the above total rent dissipation result, this implies that $p\phi(z)x_l^R F_l^R + w_k x_k^R = w_l x_l^R + w_k x_k^R$, where x_l^R substitutes for n. This simplifies to $p\phi(z)F_l^R = w_l$. □

Appendix B: Proof that $c^R(\hat{\mathbf{w}}) \leq c^R(\tilde{\mathbf{w}})$

Recall that equilibrium conditions for factor payments must respect condition (6) and either of (11) or (10). Let us express those by the following set of two equations, where parameter α is either equal to $p\phi(\tilde{z})$ or $pf'(\hat{z})$:

$$c^M(w_i, w_j) - 1 = 0, \tag{27}$$

$$c^R(w_i, w_j) - \alpha = 0. \tag{28}$$

Differentiating these two expressions with respect to parameter α and making use of Cramer's rule yields:

$$\frac{\partial w_i}{\partial \alpha} = \frac{-c_j^M}{c_i^M c_j^R - c_i^R c_j^M}, \tag{29}$$

$$\frac{\partial w_j}{\partial \alpha} = \frac{c_i^M}{c_i^M c_j^R - c_i^R c_j^M}. \tag{30}$$

Now according to Shephard's lemma, c_i^S denotes the quantity of factor i used in sector S per unit of output, i.e., $y^S c_i^S = x_i^S$, $S \in \{M, R\}$, and similarly for factor j. Inserting this into the above two equations yields:

$$\frac{\partial w_i}{\partial \alpha} = \frac{-y^R x_j^M}{x_i^M x_j^R - x_i^R x_j^M}, \tag{31}$$

$$\frac{\partial w_j}{\partial \alpha} = \frac{y^R x_i^M}{x_i^M x_j^R - x_i^R x_j^M}. \tag{32}$$

We consequently have:

$$\frac{\partial w_i}{\partial \alpha} < 0 \quad \text{iff} \quad \xi_i(\mathbf{x}^M) > \xi_i(\mathbf{x}^R), \tag{33}$$

$$\frac{\partial w_j}{\partial \alpha} > 0 \quad \text{iff} \quad \xi_i(\mathbf{x}^M) > \xi_i(\mathbf{x}^R). \tag{34}$$

Without loss of generality, we posit that $\xi_i(\mathbf{x}^M) > \xi_i(\mathbf{x}^R)$.[18] The above therefore implies that an increase in α leads to a decrease in w_i/w_j.

Assume now that $c^R(\hat{w}) > c^R(\tilde{w})$. This implies that α must take on a larger value under RA than OA and thus, according to the above result, $\hat{w}_i/\hat{w}_j < \tilde{w}_i/\tilde{w}_j$. But $c^R(\hat{w}) > c^R(\tilde{w})$ also implies that $\hat{z} < \tilde{z}$, as can be readily seen from Fig. 2. Now according to Corollary 2, $\xi_i(\mathbf{x}^M) \geq \xi_i(\mathbf{x}^R)$ implies $\hat{w}_i/\hat{w}_j \geq \tilde{w}_i/\tilde{w}_j$ when $\hat{z} < \tilde{z}$. A contradiction. □

Appendix C: Proof that $\hat{z} < \tilde{z}$

Assume to the contrary that $\hat{z} \geq \tilde{z}$. Then, it must be the case that $c^R(\hat{w}) < c^R(\tilde{w})$. In line with the analysis of Appendix 1 above, this calls for a lower value of α under RA as compared to OA and therefore $\hat{w}_i/\hat{w}_j > \tilde{w}_i/\tilde{w}_j$. Consequently, factor i is used less intensively under RA than OA and, as can be readily seen in Fig. 1, this requires $\hat{\mathbf{x}}^R \ll \tilde{\mathbf{x}}^R$ and thus $\hat{z} < \tilde{z}$. A contradiction. □

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[18] Note that the problem is undefined for $\xi_i(\mathbf{x}^M) = \xi_i(\mathbf{x}^R)$.

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